IMPERIAL INSTITUTE

OF

AGRICULTURAL RESEARCH, PUSA.

THE SCIENTIFIC MONTHLY

THE
SCIENTIFIC MONTHLY

EDITED BY

J. McKEEN CATTELL

VOLUME XI

JULY-DECEMBER, 1920

NEW YORK
THE SCIENCE PRESS
1920

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JULY, 1920

THE ECONOMIC IMPORTANCE OF THE SCIENTIFIC WORK OF THE GOVERNMENT[1]

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SCIENCE IN THE WAR

THE Great War was based very largely on science and engineering. During the twenty-five years preceding the outbreak of the war the enemy had developed science and the practical applications of science in a wonderful way. He had fostered the industries, developed shipping and foreign trade, and promoted scientific research and education until the German nation stood in the forefront of the nations of the earth. With a complete misunderstanding of race psychology and an utter lack of appreciation of moral values, the enemy had prepared for a sudden attack with crushing force when a favorable occasion should arise. When the blow fell the allied nations were unprepared, not only for lack of armies and munitions, but for lack of industrial equipment, transportation facilities, and scientific development. Holding the enemy at bay under fearful odds while they built up their armies and their industries, the allied and associated powers utilized all the resources of science and engineering and a vast amount of accumulated treasure to make good their initial deficiencies and gain strength enough to wear out and overcome the enemy. In this titanic struggle scientists, engineers and captains of industry were mobilized by the tens of thousands, and men and women in the industries by the tens of millions, in order that the soldiers and sailors in the armies and the fleets might be adequately supplied with food, munitions and equipment. The wonderful achievements of science under the pressure of necessity demonstrated the economic possibilities of

[1] Address before the Washington Academy of Sciences, May 20, 1920.

scientific research. This demonstration was not altogether new, but the war brought it home more forcefully, and at its close one felt that never again would anybody question the importance and economic value of scientific investigation.

NECESSITY FOR INCREASED PRODUCTION

The war was conducted on such a gigantic scale that the world's supply of raw and manufactured materials was largely exhausted. The increased demand thus caused for labor and commodities, together with the inflation of currency and credit and in many cases the reduced efficiency of labor has raised prices beyond all precedent. Hardship and suffering have come to hundreds of millions of people throughout the world and political and economic confusion generally has resulted.

The cost of living during the war increased considerably, but wages were so high that many classes of workers were more prosperous than ever. The government directed the channels of trade and controlled the supplies of materials with much success, and prices in most cases were kept within bounds. With the end of the war came an end of governmental control, and also with many an end of economy and thrift, and for these and other reasons prices have been mounting steadily ever since. Increased costs led to industrial unrest, strikes, high wages and further rise in prices. Profiteering has been denounced in the press and sought out by the government, but the average of prices continues to rise. It is generally agreed that in order to bring down prices it will be necessary (1) to contract currency and credit, (2) to economize in the use of necessities and luxuries, and (3) to utilize raw materials and labor more effectively and expand the production of commodities. The first remedy must be worked out by financiers and economists. The second might be accomplished by a nation-wide campaign for thrift and economy; and the third would be greatly aided by cooperative study and scientific and technical research on a comprehensive scale.

THE GOVERNMENT AND INCREASED EFFICIENCY

There is a shortage of labor in the country, and a tendency to shorten rather than to lengthen the hours of labor. If, therefore, production is to be increased without increased labor, it is necessary to increase the productivity of labor; that is, to increase the efficiency of men, of machines and of manufacturing methods. To economize in the use of staple commodities and luxuries, to reduce the waste of raw materials, to make

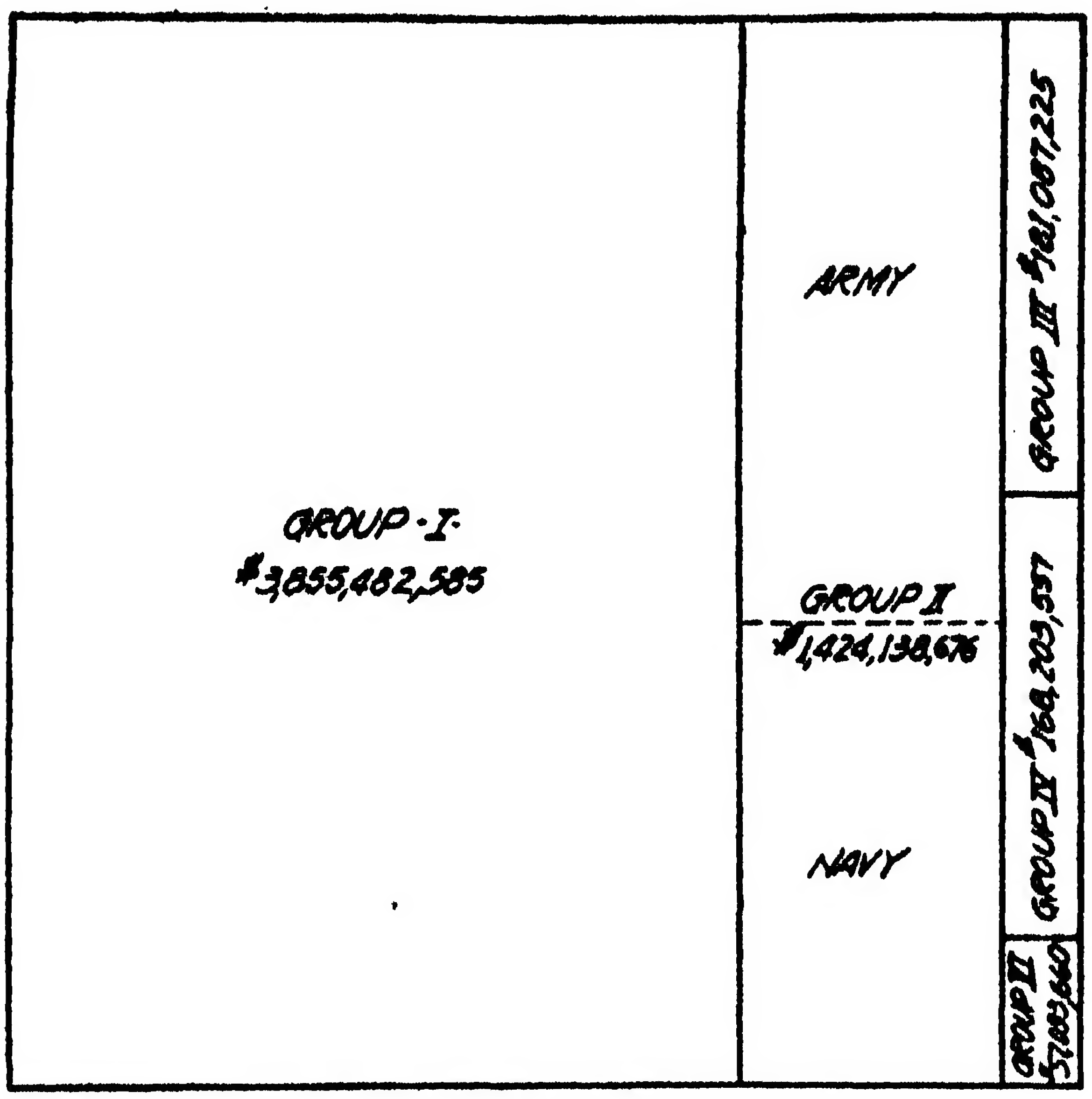
use of cheaper materials, to increase the efficiency of men, of machines and of processes, on a nation-wide scale and at an early date will call for intelligent and energetic effort, comparable in difficulty and importance with the task before the country in 1917 when we entered the world war. It is not merely in order to reduce the cost of living to those millions whose incomes have not increased in proportion to the rise in prices, and who in many cases are suffering hardship and distress; but it is to allay industrial discontent and forestall economic and political disturbance or even disaster. The confusion and inequity that have resulted from the rise of prices threaten the stability of society. The governments of the world are face to face with the problem of improving conditions and allaying discontent. To hold that governments cannot or should not deal constructively with the most serious problems of society, but that such matters should be left to chance, without organized effort or leadership, is not a satisfactory position to take after the successful experience with government leadership in the war. The old idea that the less government we have the better, no longer applies, if it ever did. Society is made up in part of a multitude of groups, some of which are highly organized, and many are seeking the advantage of the group rather than of society as a whole. The government represents the interests of society as a whole, and its problems and responsibilities have increased enormously in recent years.

Three Kinds of Governmental Functions

Henry C. Adams, in his treatise on the Science of Finance, classifies governmental functions into three groups, namely, (*a*) The protective functions of government, (*b*) the commercial functions of government and (*c*) the developmental functions of government.

(*a*) The protective functions of government are divided into three principal classes: (1) Protection against invasion or encroachment from without is provided by the army and navy, and this has always been an important and relatively expensive department of a national government. (2) Protection of life, property and reputation, which is accomplished through police, fire departments and the courts. (3) Protection against the spread of disease, either physical or social. As crime is looked upon as a phase of social disease, this will include prisons, asylums, sanitary provision, public charities, etc.

(*b*) The commercial functions of government include those which render a service for which payment is made by the in-



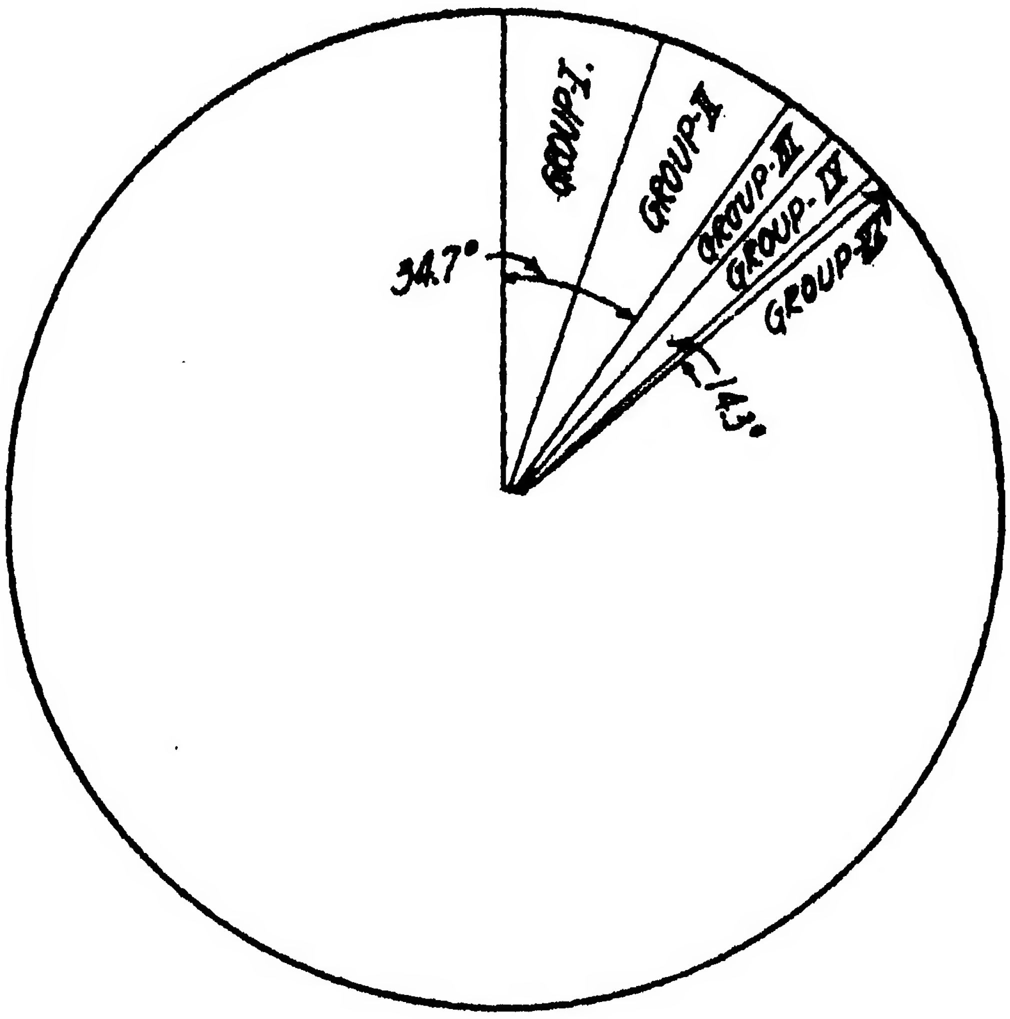
Distribution of Government Appropriations For Fiscal Year 1920.

dividuals served, and are in general self-supporting. They address themselves primarily to the personal needs of the citizen rather than to the social needs of the state, and are performed by the state because it can render the service better or cheaper than private agencies. Examples are the post office, and in some cases railways, canals, telegraphs and other public utilities, patents and insurance.

(*c*) The developmental functions of government "are such as spring from a desire on the part of society to attain higher forms of social life." Society is not merely a collection of individuals, but is a conscious organism, and the interests of society require collective action in developing itself. This includes, (1) public education, (2) public recreation, (3) providing those legal and administrative conditions in which private business will be conducted in a just and equitable manner, (4) public investigation and control of public utilities, (5) developing the resources and wealth of the state, which includes scientific and industrial research.

Developmental Functions of the Federal Government

These three classes of functions are exercised to some extent by municipal and state governments as well as the federal government. For the present we are concerned only with

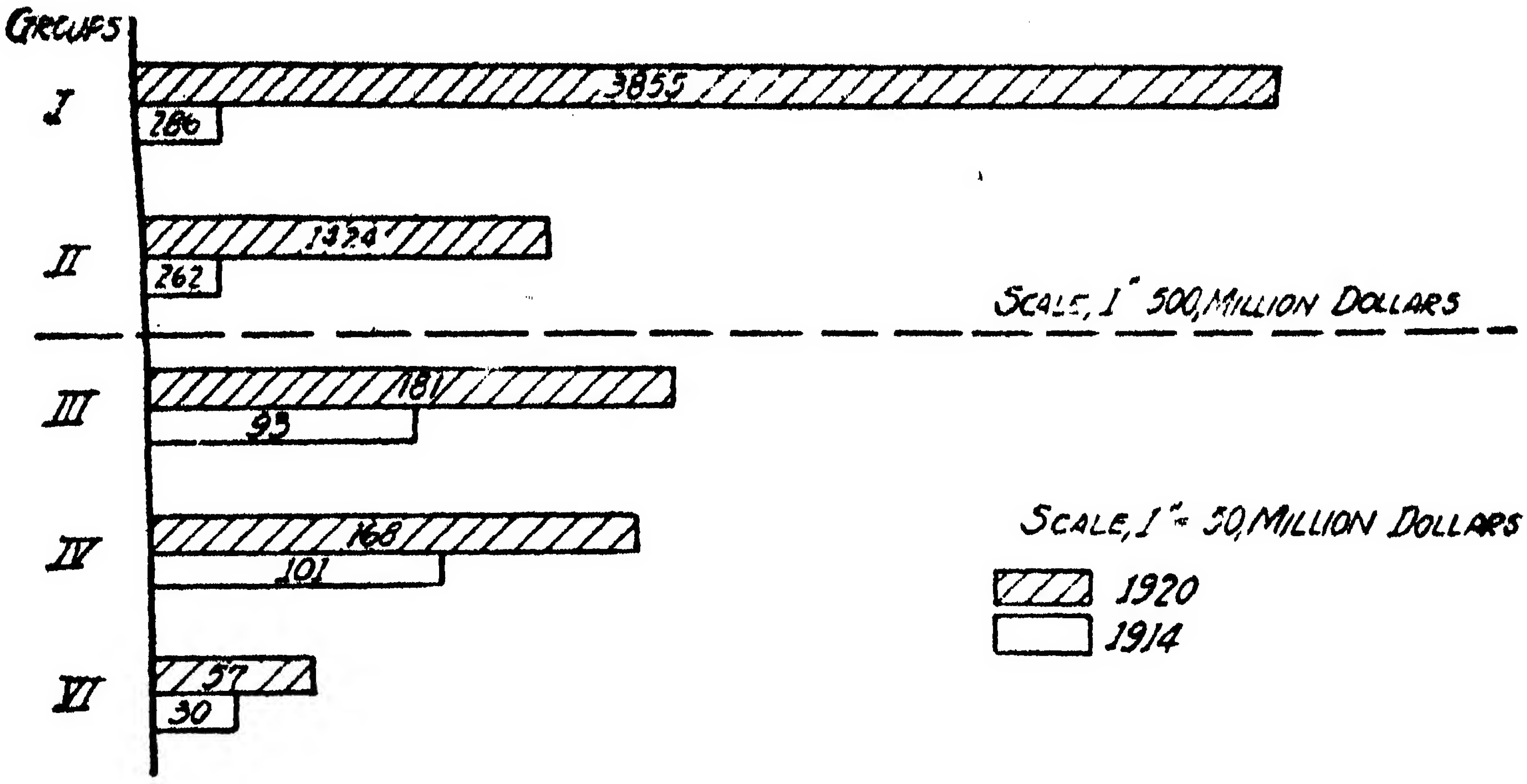


Appropriations for Fiscal Year 1914 on 1920 Circle
Appropriations for 1920 = 360°
Appropriations for 1914 = 49°

those exercised by the federal government. The powers of the federal government were delegated to it by the states, and were intended to be those required for the exercise of sovereignty by the nation in its relation with other nations, the maintenance of a national army and navy, the provision of a national currency, a common postal system, a uniform system of weights and measures (although this was not carried out as intended), the regulation of interstate commerce, etc.

In the early years of our history, society was relatively simple, communication and travel were infrequent, and each community was comparatively independent. Hence local governments were, in many respects, more important than national. With the developments in transportation and communication which have resulted from steam and electricity, the forty-eight states have come very close together, commerce and industry have much in common everywhere, uniformity of practise and uniformly good practise are generally desired, and it has been a problem how to avoid confusion of administration and industrial practise when there were so many legislatures and administrative bodies acting independently of each other. This has been partly accomplished by the cooperation of federal agencies with state bodies, leaving the legal authority with the states.

Many protective and developmental functions have long been exercised by the federal government because they were of

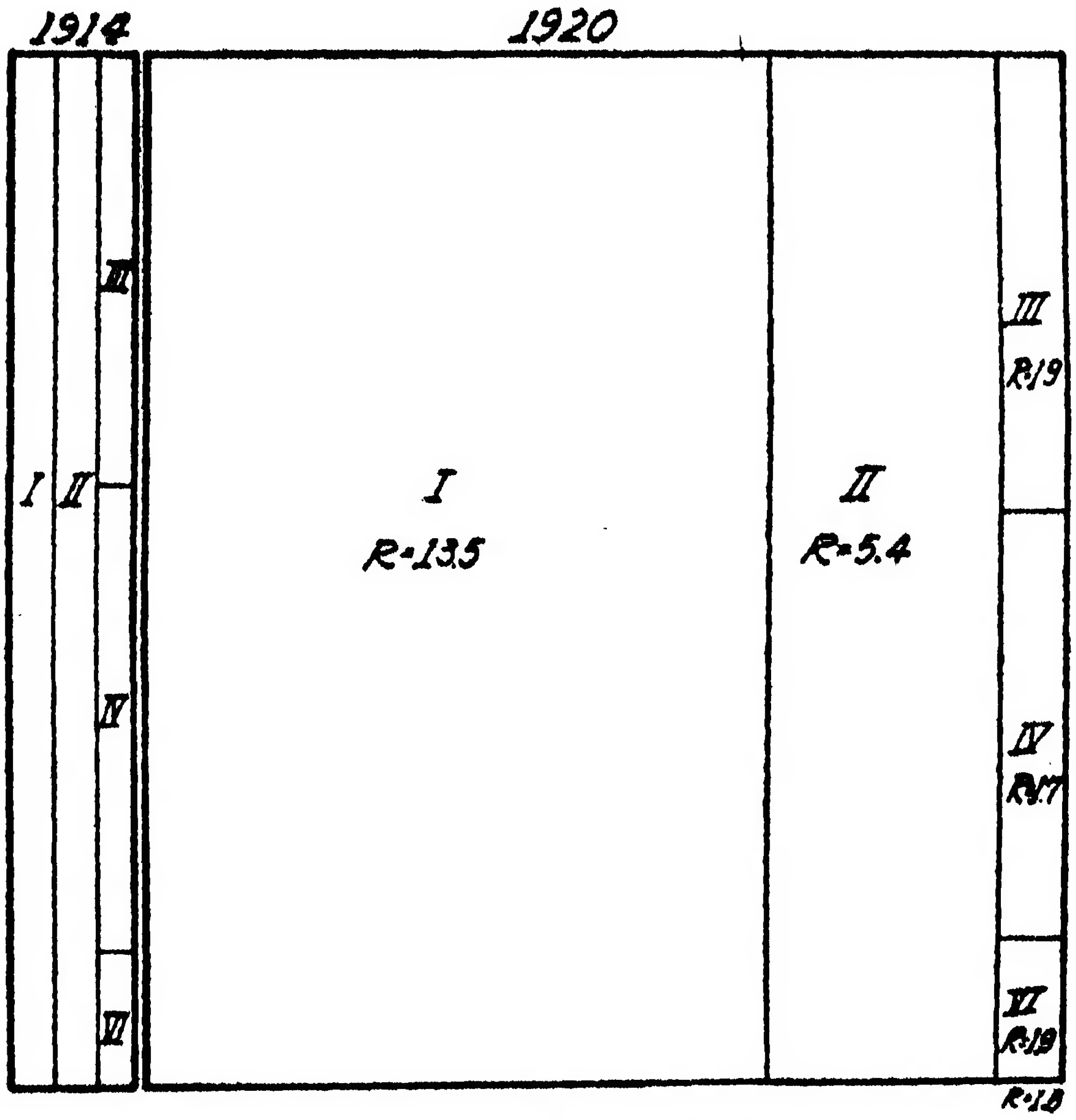


Comparison of Government Appropriations for Fiscal Years 1920 and 1914
(Figures in Bars Represent Millions of Dollars)

common interest to all the people, and they could be performed more effectively and more economically by the federal government than by the several states, and there was no practicable way of getting the states to work in harmony on a common program. The people who support the federal government are the same people who support the forty-eight state governments, and hence the plan of acting together through the federal government in performing functions of interest to all is not only economical and efficient but logical and just.

Scientific Research a Luxury or a Necessity?

For many years the revenues of the federal government were ample and easily obtained. Taxation was indirect and not felt and many of the developmental functions of the government were exercised with little question or objection. The Great War involved enormous expenditures and increased the fixed charges due to the public debt and other war obligations to several times the former budget. The result is that expenditures for education, scientific research and development work are severely scrutinized, and the question is raised as to whether we can afford to carry on such work on a generous scale. It is, of course, proper that every item in the national budget be closely scrutinized, and that nothing be passed which cannot justify itself. It is desirable, therefore, to inquire whether scientific research as carried on by the federal government is a luxury or a necessity; whether it is something to be



Comparison of Government Appropriations by Groups
For Fiscal Years 1914 and 1920
Total for Groups-1914 = 773,607,184.
Total for Groups-1920 = $5,686,005,706.
R = Ratio of 1920 to 1914

enjoyed when taxes are light and curtailed when taxes are heavy; or whether it is creative and wealth producing, and therefore to be increased and developed when expenses are abnormally large and a heavy debt must be liquidated. The question is, in short, whether scientific and industrial research and education are like good seed and fertilizer to a farmer, which are essential to the best success; or whether they are as luxuries to the rich which consume but do not produce, and which should be curtailed when necessary expenses increase.

The National Budget

In order to discuss the question concretely and with reference to actual conditions, let us examine the national budget as it stands for the current fiscal year, with appropriations amounting to a total of $5,686,005,706, as given in the regular supply bills and three deficiency bills prior to May 1, 1920. For convenience, we may divide it into six parts as follows:

Group I. **Obligations arising from recent and previous wars, including interest on the public debt, pensions, war risk insurance, rehabilitation and care of soldiers, deficit in the operation of railways, expenditures of the Shipping**

	Board, European food relief and the bonus to government employees to partially cover the increased cost of living due to the war, a total of	$3,855,482,585
Group II.	War and Navy Departments, expenses somewhat above a permanent peace-time basis....	$1,424,138,677
Group III.	Primary governmental functions, including Congress, President and White House staff, courts and penal establishments, departments of Justice, State, Treasury, Interior, Commerce, Labor, Interstate Commerce and other commissions, one-half the District of Columbia including all the necessary functions of government other than defense, except the commercial activities of Group V. and the research, education and developmental work of Group VI.	$ 181,087,225
Group IV.	Public works, including rivers, and harbors, public buildings, reclamation service, post roads, national parks and railway in Alaska.	$ 168,203,557
Group V.	Commercial or self-supporting activities, including the Post Office, Patent Office, Land Office, Panama Canal, and Housing Corporation, which taken together earn their expenses	
Group VI.	Research, educational and developmental, including the wide range of work of the Agricultural Department, Geological Survey, Bureau of Mines, Coast and Geodetic Survey, Bureau of Standards, Bureau of Fisheries, Bureau of Foreign and Domestic Commerce, Bureau of Labor Statistics, Women's and Children's Bureaus, Vocational Education, Colleges for Agriculture and Mechanical Arts, Library of Congress, Smithsonian Institution and the Public Health Service	$ 57,093,661
	Total	$5,686,005,705

Appropriations for Fiscal Year Ending June 30, 1920

(As given in regular supply bills and three deficiency bills prior to May 1, 1920)

Group I. Expenditures arising from Recent and Previous Wars

Interest on the public debt[2]	$1,076,637,000.00
Pensions	216,382,540.00
War risk insurance (estimated expenses above receipts $102,000,000)	120,852,806.00
Federal Board for Vocational Education (rehabilitation).	30,000,000.00
Public Health Service (care of soldiers, etc.)	25,901,517.14
Soldiers' and sailors' homes, cemeteries, etc.	14,639,010.00
Federal control of transportation. (Deficit and Advances)[3]	1,550,000,000.00

United States Shipping Board (estimated expenses, including funds reappropriated)		685,842,000.00
European food relief		100,000,000.00
Other expenditures due to recent war		4,467,712.46
Bonus to government employees		30,760,000.00
	67.81%	$3,855,482,585.60

Group II. War and Navy Departments (Somewhat above Permanent Peace-time Expenditures)[4]

War Department—Military	$797,913,898.95	
Civilian	6,373.949.12	$804,287.848.07
Navy Department—Military	617,621,353.56	
Civilian	2,229.474.94	619,850,828.50
	25.02%	$1,424,138,676.57

Group III. Primary Governmental Functions

Legislative		$ 10,837,936.47
Executive (President and White House Staff)		224,080.00
Judicial (Federal Courts, Penal Establishments, etc.)		12,124,884.24
Department of Justice		4,483,671.70
State Department		12,331,371.97
Treasury Department:		
General, including collection of customs	$ 29,065,653.22	
Internal Revenue Service	29,751,170.00	
Coast guard	8,880,523.33	
Bureau of Engraving and Printing	7,010,425.00	74,707,771.55
Department of Interior:		
General, including Alaskan Expenditures	1,940,684.92	
Indian Office and Indian Service	11,437,187.00	13,377,871.92
Department of Commerce:		
General, including Bureau of Navigation	920,725.52	
Bureau of Lighthouses	8,411,030.00	
Steamboat Inspection Service	995,890.00	
Bureau of Census	17,550,000.00	27,877,645.52
Department of Agriculture:		
Meat Inspection Service		3,000,000.00
Department of Labor-Immigration, Naturalization:		
Employees' Compensation, Conciliation, etc.		5,464,337.32
Interstate Commerce Commission		5,313,086.90
Federal Trade Commission		1,205,000.00
Civil Service Commission		548,700.00
Joint Commission on Reclassification of Salaries		50,000.00
U. S. Tariff Commission		300,000.00

[2] Disbursements for interest on public debt for the fiscal year 1920 will be somewhat less than appropriations.

[3] Appropriations to Railroads include $300,000,000 loan, but do not include the deficit from March 1 to June 30, 1920.

[4] Disbursements for fiscal year 1920 will exceed by about one billion of dollars the above appropriations for the War and Navy Departments because of balances of appropriations carried over from 1919.

Bureau of Efficiency		145,000.00
One half District of Columbia, Hospitals, etc.		9,100,867.82
	3.19%	$ 181,087,225.41

Group IV. Public Works

War Department—Rivers and Harbors	$	43,456,653.15
Treasury Department—public buildings (equipment and construction)		10,319,076.11
Repairs and maintenance of public buildings in D. C.		1,139,633.20
U. S. Reclamation Service		7,511,000.00
Department of Agriculture—rural post roads		99,000,000.00
National Park Service		777,195.00
Construction of railroad in Alaska		6,000,000.00
	2.97%	$ 168,203,557.46

Group V. Commercial or Self-supporting Government Activities

Post Office Department—Surplus, 1919	$ 2,342,851.96
Department of Interior:	
Patent Office—Surplus, 1919	106,654.10
General Land Office—Estimated Surplus, 1920	1,500,000.00
U. S. Housing Corporation—Estimated Operating Surplus, 1920	1,012,973.00
Panama Canal—Estimated Deficit, 1920	3,297,337.00

Group VI. Research, Eductional and Developmental

Department of Agriculture:		
Forest Service—less receipts of $4,750,000.00	$ 4,191,869.00	
Bureau of Animal Industry	5,783,281.00	
States Relations Service	4,905,820.00	
Bureau of Plant Industry	3,379,638.00	
Cooperative Agricultural Extension Work	3,080,000.00	
Bureau of Markets	2,811,365.00	
Weather Bureau	1,880,210.00	
Bureau of Entomology	1,371,360.00	
Bureau of Chemistry	1,391,571.00	
Bureau of Biological Survey	742,170.00	
Bureau of Public Roads	594,320.00	
Bureau of Soils	491,235.00	
Bureau of Crop Estimates	372,484.56	
Bureau of Farm Management and Farm Economics	302,590.00	
Horticultural and Insecticide	252,940.00	
Miscellaneous Investigations	2,589,400.00	
General Administration	1,715,626.58	$35,855,830.14
Department of the Interior:		
Geological Survey	$ 1,661,353.50	
Bureau of Mines	1,216,897.00	
Bureau of Education	241,960.00	
Howard University	121,937.75	3,242,148.25

Department of Commerce:		
Coast and Geodetic Survey ....$	1,925,870.03	
Bureau of Standards	1,892,260.00	
Bureau of Fisheries	1,274,490.00	
Bureau of Foreign and Domestic Commerce	912,510.00	6,004,630.03
Department of Labor:		
Bureau of Labor Statistics............$	321,690.00	
Women's and Children's Bureaus	320,140.00	641,830.00
Treasury Department—Public Health Service		4,025,440.00
Federal Board for Vocational Education		3,182,000.00
Colleges for Agricultural and Mechanic Arts		2,500,000.00
Library of Congress		925,825.00
Smithsonian Institution		715,957.51
	1.01% $	57,093,660.93

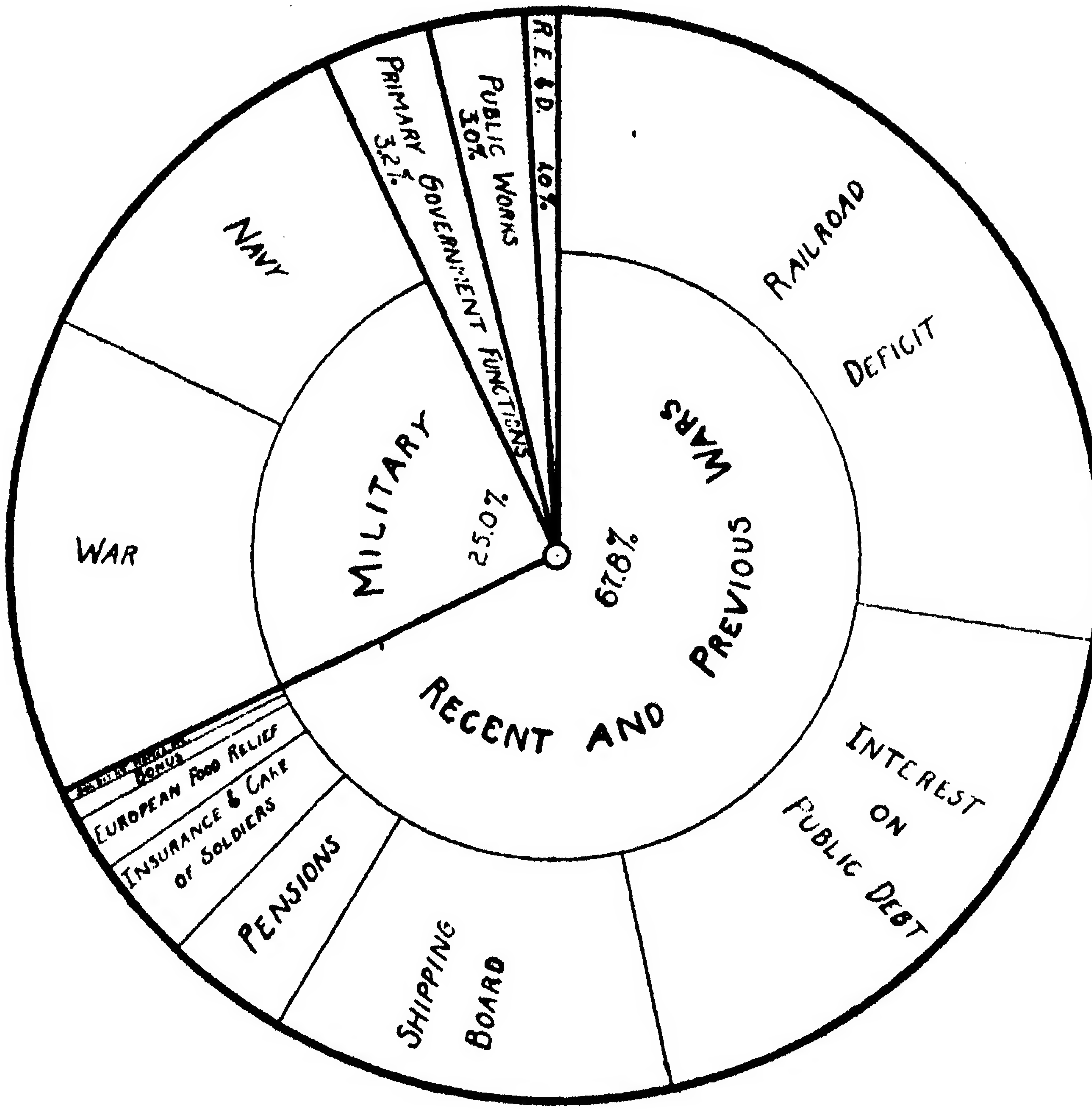
SUMMARY

Group I.	Expenditures arising from Recent and Previous Wars	$3,855,482,585.60	67.81%
Group II.	War and Navy Departments....	1,424,138,676.57	25.02%
Group III.	Primary Government Functions..	181,087,225.41	3.19%
Group IV.	Public Works	168,203,557.46	2.97%
Group VI.	Research, Educational and Developmental	57,093,660.93	1.01%
	Total	$5,686,005,705.97	100.00%

ONE PER CENT. FOR RESEARCH, EDUCATION AND DEVELOPMENTAL WORK[2]

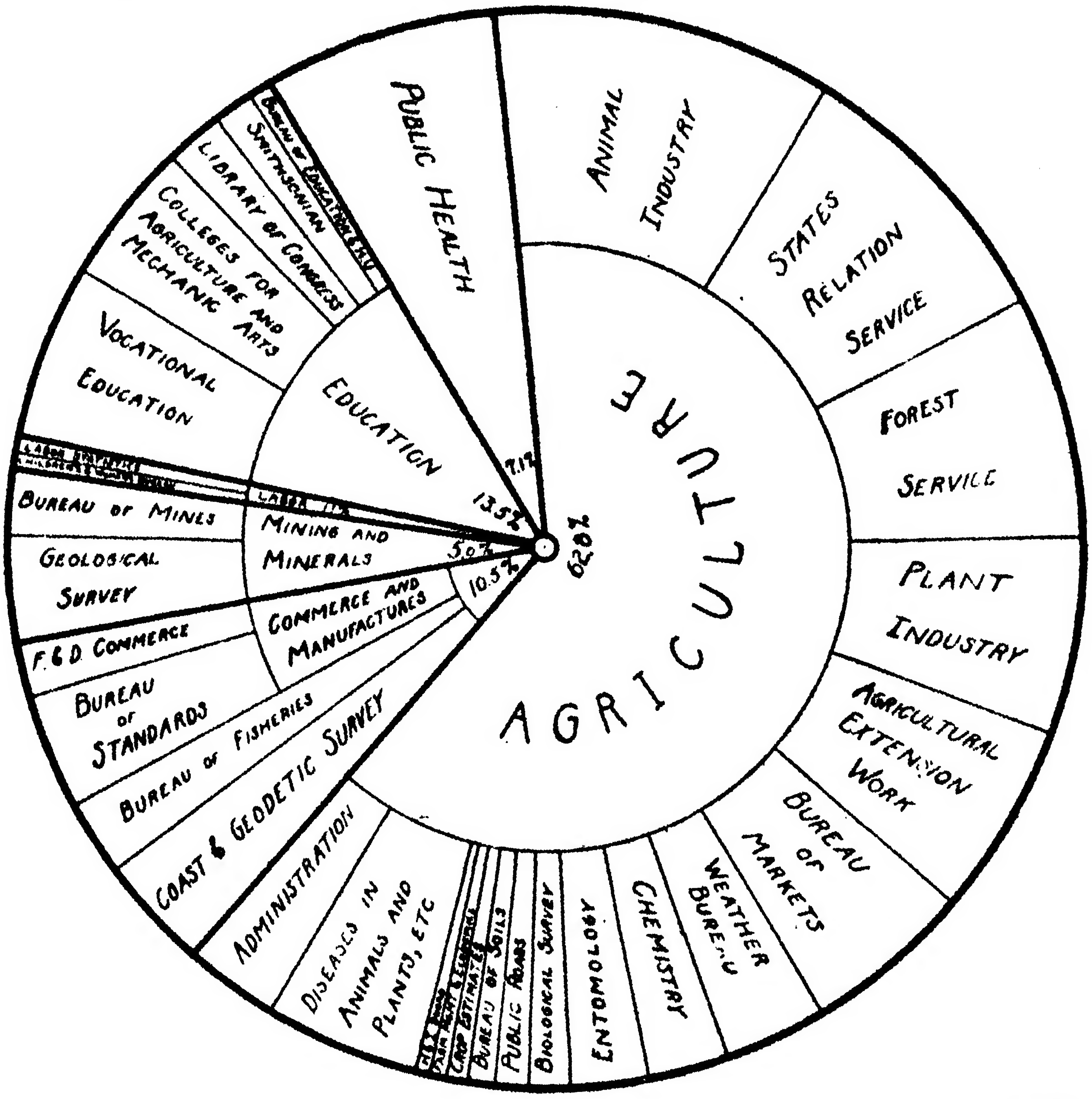
The first two groups together amount to 92.8 per cent of the total; public works amount to 3 per cent, primary governmental functions 3.2 per cent, and research, education and developmental work 1 per cent. The population of the country being about 110,000,000, the total budget is about $50 per year per capita, of which fifty cents per year per capita is expended for the wide range of research, education and development work included in Group VI. That is, of the fifty dollars per year per capita collected for all purposes, a dollar and a half per year per capita is spent for what is here called the primary functions of government; nearly as much more is put into

[2] For the next fiscal year, the appropriations needed for the railroads and Shipping Board, and for the Army and Navy, will be very much less than for the current fiscal year. The Treasury Department therefore expects to be able to make a very substantial reduction in the floating debt, now amounting to nearly three billions of dollars. The appropriations for Group VI for the next fiscal year are substantially the same as for this year. The ratio of Group VI to the total will therefore be substantially the same as at present (namely, one per cent), if we include, as we should, the payments on floating debt and sinking fund in Group I, and if the total revenues for next year are approximately the same as this year.



DISTRIBUTION OF GOVERNMENT EXPENDITURES FOR FISCAL YEAR 1920

public works, and fifty cents per year is put back into research, educational and developmental work, to promote scientific research, to increase production and efficiency, to develop wealth, to promote the public health, and to conserve our natural resources. This is a very small part of the total, hardly enough to be regarded as a burden on the nation. Indeed, one is led to wonder whether the total burden of taxation would not be lighter if the expenditure for scientific and developmental work were increased; if, for example, it were one dollar per year per capita instead of fifty cents. In other words, if $110,000,000 were expended annually for this creative and productive work, would it not be easier to collect the five and a half billions for other purposes? To answer this question intelligently, it will be well to look a little closer into how the fifty cents per capita is expended and what is accomplished thereby.



DISTRIBUTION OF EXPENDITURES OF GROUP VI FOR RESEARCH, EDUCATION AND DEVELOPMENT

WORK OF THE AGRICULTURAL DEPARTMENT

Nearly two thirds of all the expenditures made under Group VI. are for the work of the Agricultural Department. Agriculture is the most important industry of the nation. Agricultural and animal products amount possibly to twenty-five billions of dollars per year. Food has risen in price in recent years along with other products, partly because of higher wages and higher cost of machinery and supplies used by farmers, but largely because the urban population has increased faster than the rural and the demand for food products has increased faster than the supply. It is of prime importance to city dwellers that food products be produced in greater quantity, and this requires an increased efficiency or an increased rural population, or both. The Agricultural Depart-

ment carries on a wide range of educational and experimental work in order to increase the production of farm products and to promote the interest of the farmer in his work, as well as to make life on the farm and in rural communities more attractive. This not only benefits the farmer, but tends to keep food prices within reason for city dwellers. It is therefore serving all the people, and its work was never so much needed as at the present time. It is spending about $1.50 for every $1,000 of value of agricultural and animal products, and without doubt the results achieved pay many times the cost of the work. The work of the Forest Service is nearly self-supporting, and might have been put into Group V. This year, owing to unusual forest fires, its deficit is larger than usual. Ultimately, it will be more than self-supporting. The work of the various bureaus is of great importance and absorbing interest, but time does not permit even a brief description.

THE GEOLOGICAL SURVEY AND THE BUREAU OF MINES

The Geological Survey and the Bureau of Mines are concerned with the mineral industries of the country; coal, iron, copper and the other industrial and precious metals, oil, gas and the water supply and the topography of the land. Our country is rich in these natural resources and we are spending them in prodigal fashion. It is the business of these two bureaus to survey and map the distribution of metals and minerals; to look for new sources of supply; to gather statistics and to increase safety and efficiency in the mining and metallurgical industries; and to consider what can be done to conserve these natural resources which, unlike the products of agriculture, are not reproduced in annual cycles, but when once used can never be replaced. In addition, topographic and water power surveys are made and mapped. The products of the mineral industries of the country amount possibly to six billions of dollars per year. They are indispensable to our manufactures, and a most important part of our national wealth. If these two bureaus were to spend in this important work of research and development, an amount equal to one dollar in a thousand of the annual value of mineral products, it would amount possibly to six millions of dollars per year, which is more than double present expenditures. Can there be any doubt that such a sum expended in the interest of the public that pays the entire cost, and must bear the burdens of any inefficiency that exists in the industries, would be amply repaid? For example, millions of dollars are worse than

wasted every year in accidents that could be prevented. Mining is one of the most hazardous of industries. The Bureau of Mines has done a great deal of valuable work, both in research and education, to make mining safer; but there is need for a great deal more than it has been able to do. The results of such work are available in all the states where mining is carried on. It can generally be done better, and far more economically, than if done by the states unaided by the federal government. These two bureaus are doing a work of great economic importance at a cost to the people of this country of three cents per capita per year. If it were doubled the burden would be only slightly increased, but the service rendered in the increased efficiency of production and fewer accidents and more intelligent use of our natural resources would be very considerable. This is a splendid example of the economic and social value of cooperation of all the people through the agency of the federal government in doing efficiently what is needed by all.

The Bureaus of Standards and of Foreign and Domestic Commerce

The Bureau of Standards develops and maintains the standards of length, mass, volume, temperature, electrical and optical measurements, prepares standard chemicals and does many other kinds of fundamental work; it does testing for the government and the public, and it carries out scientific and industrial researches to develop the industries. A very large amount of work is done for the army, navy and other departments and for state institutions, so that not more than one half of its total expenditures can properly be considered as used for the development of the industries. Excluding food products, tobacco and liquors, the annual value of manufactured products in this country, over and above the value of the raw materials entering into them, is possibly $12,000,000,000. The Bureau of Standards spends this year a sum not more than 15 cents per $1,000 of manufactured products in all its work, and as stated above, not more than one half of it is for the purpose of developing these manufactures. If this sum could be considerably increased, it would enable a much larger amount of work to be done and the work could be carried on more efficiently. I shall give examples presently of such work, and you may judge whether it would be profitable.

While the Bureau of Standards maintains and makes available the standards of measurement, of quality, of performance, and of practise, for commerce and the industries, and engages

in research to develop the industries, the Bureau of Foreign and Domestic Commerce is concerned with the development of commerce and our export trade. The importance of foreign trade to a great nation, and the opportunity and duty of the government in fostering that trade in all legitimate ways, need no emphasis on this occasion. In view of the position of America as a world power, and in view of the general desire that our foreign commerce may be not only profitably but creditably conducted, it would seem that this function of the government would be developed and strengthened.

THE COAST SURVEY AND THE BUREAU OF FISHERIES

The Coast and Geodetic Survey is one of the oldest branches of the government doing scientific and technical work, and until the establishment of the Bureau of Standards, kept the standards and did the testing of weights and measures. It is charged with the survey of the coasts and rivers to the head of ship navigation, and the publication of charts, giving the results of base measurements, triangulation, topographic and hydrographic surveys, deep sea soundings, temperature, magnetic observations, gravity research, determination of heights, latitude, longitude, and reference points for state surveys. The work is very fundamental and important and has been done with a high order of precision and thoroughness, and with marked credit to the government.

The purpose of the Bureau of Fisheries is the stimulation of the production and consumption of fish as an important source of food. To stimulate production, scientific research on the habits and propagation of fish is carried on. The breeding of fish and their distribution into lakes and streams is done on a large scale. In all of this work, but particularly in connection with the propagation of fish and the protection of fish against lawlessness, the Bureau cooperates with the various states. The responsibility of the government for work of this kind is obvious, and there can be no doubt as to its being profitable.

THE BUREAU OF LABOR STATISTICS AND THE WOMEN'S AND CHILDREN'S BUREAUS

The Bureau of Labor Statistics gathers the statistics of wages in the various industries and of the cost of living, and publishes much valuable material of interest to labor and capital. The prosperity and happiness of all the people depend to a considerable extent upon industrial peace and freedom

from strikes and disorder. Industrial peace and contentment require justice and fair dealing between employers and employed. In order that both may know what is just and fair, statistical information as to wages and changes in prices and the cost of living is essential. It is probable that the greatest obstacle to a good understanding between employers and employed is lack of information. Suspicion and prejudice often give way to sympathy and understanding when full information, including information about what others are doing, is made available. The good results achieved by generous treatment of labor should be put before all employers, and if the government would spend more on research and education in this important field, might it not save much that is now spent in other directions? And might not the public be saved much both in expense and inconvenience that results from industrial warfare? This subject is of such tremendous and far-reaching importance that one is led to ask whether the government is doing as much as it should in this connection.

The work of the Women's and Children's Bureaus is relatively new, but of great importance. Women are employed in the industries more than ever before, and the high wages and shortage of labor increase the pressure for the work of children. In the interest of the state, apart from considerations of humanity, women and children should be protected in the industries; and the work of these two bureaus is therefore of fundamental importance. It seems likely that it will grow rapidly in magnitude and occupy a larger place in the public's thought.

Educational Work

The Bureau of Education collects and disseminates information concerning educational matters. The federal government has never taken a very active part in the educational work of the country. Whereas cities spend an average of $6 per year per capita for education and the states and private agencies about $3 per year per capita, the federal government spends only 6 cents per capita per year, including the sums expended in vocational education and assistance granted to colleges of agriculture and mechanic arts. Common schools and high schools are maintained by towns and municipalities, with some aid from the state. Normal and secondary schools, colleges and universities, are maintained by the states and private agencies. Indeed private schools and privately endowed colleges and universities constitute a very important part of our educational system. The federal government, on

the other hand, has no national university, and spends no money in the District of Columbia on higher education, except for Howard University for colored students. For many years the Bureau of Education has been doing a valuable work in keeping a record of the educational work of the country. Its support might well be greatly augmented, its scope broadened and its activities and responsibilities correspondingly increased. We believe thoroughly in this country in popular education. We believe that the welfare of the state demands an intelligent electorate, and that material prosperity goes with education. The war revealed an unsuspected percentage of illiteracy in the men examined for military service. A million men in the draft could not read and write. The federal government might well take greater responsibility in matters of education and coöperate more actively with the states, setting standards for educational work and giving direction and encouragement where they are needed. A department of Education with a cabinet member at the head, has more than once been proposed, and is even now being discussed.

Better facilities for higher education in the District of Columbia would be of great value to thousands of federal employees, as well as to other residents of Washington. The desire of federal employees for educational advancement should be encouraged and the needed facilities supplied, partly for their own sake and partly because they would thereby be enabled to render better service to the government. Washington is the proud capital of the richest nation on earth, and yet there are few cities in America and few capitals anywhere in the world where so little is done for higher education.

Recently, the Federal Board for Vocational Education has been established, and a substantial sum placed at its disposal. The need for vocational training was emphasized by the results of tests made in the army. Of men claiming expert knowledge of the skilled trades, only six in a hundred were found to be really expert. The Board assists the states financially and otherwise in developing and maintaining a system of vocational training. Such work is greatly needed as industry itself fails to supply the training necessary.

For many years the government has been cooperating with the states by paying a certain sum of money each year to one college in each state for the teaching of agriculture and mechanic arts. This was provided for under the Morrill act, and these payments now amount to $2,500,000 per year. In most cases these sums are a very substantial help to the institutions

receiving them, and undoubtedly do a very great deal of good in the aggregate.

An English journal, commenting on the increased sums allotted in the English budget for next year to scientific and industrial research, has this to say: "Education and the financing of that education are important subjects. Indeed, we do not hesitate to say that upon the right methods of instruction being followed depends very largely the future prosperity of the nation."

The Library of Congress and the Smithsonian Institution

The Library of Congress is a great national institution, corresponding to the British Museum and the Bibliothèque Nationale. It is properly grouped with the educational institutions of the government, and it is an institution of which all Americans are proud. It is a great library, housed in a beautiful building, useful to thousands, enjoyed by hundreds of thousands. The country approves a generous policy toward this activity of the government, devoted as it is to art and education.

The Smithsonian Institution and the National Museum are national institutions devoted to science, art and natural history. The Smithsonian Institution has a private endowment, but the greater portion of its funds come from the government. It carries out scientific researches in the physical and natural sciences and has extremely valuable collections in its museums and art galleries. The government has not done as much in promoting art and collecting works of art as have many other governments, and it is to be hoped that much may be done in the future to compensate for past neglect of these matters.

The Public Health Service

The Public Health Service is one of the most important of the agencies doing work of research and education. It maintains supervision over incoming vessels to prevent the introduction of diseases; to prevent the spread of diseases between the states it makes inspections and cooperates with the state departments of health; statistics of diseases are collected and interpreted; and scientific research is carried out to develop methods of preventing the spread of disease.

The Service has recently formulated a comprehensive health program to be carried out on a nation-wide scale by the active cooperation of federal, state and local authorities

and voluntary organizations. That these needs are urgent is shown by the fact that more than one third of all men examined under the draft during the war were rejected for physical defects and diseases. The Surgeon General states that in large measure these defects and diseases could have been prevented had proper attention been given to them, especially in childhood. This unsatisfactory condition of the public health shows the need of greater attention on the part of the federal government, and more systematic cooperation between local and national agencies. This systematic cooperation is obtained by the federal aid extension principle, as in the construction of good roads, and agricultural education.

A large amount of most valuable medical, statistical and research work is carried on by the Public Health Service, which has been greatly developed in recent years. The opportunities presented in this work for growth and increased usefulness are almost boundless. In addition to its work in connection with the public health, a large amount of work is done in the care and rehabilitation of sick and wounded soldiers.

The foregoing brief outline of the activities of the various government agencies included in Group VI gives a very incomplete statement of the research and educational work done by the government. It is, however, intended to convey some idea of the wide range and important character of this work, and its great possibilities for development if more adequate provision could be made for its support. A portion of the work of the Bureau of Chemistry, the Bureau of Standards, the Coast and Geodetic Survey and other bureaus of Group IV would have been included in Group III if the work of the bureaus had been split up and the classification had been more detailed and exact. On the other hand, a portion of the work of the Naval Observatory, the Bureau of the Census, and other bureaus in other groups is scientific and educational. It is not possible to make a simple classification that is perfectly exact, but it is believed that the one given is sufficiently exact for the purpose. The Public Works group has value in economic development, but it is not research and educational, and is quite different from most of Group VI. It is now proposed to speak more in detail of one important kind of scientific research, namely, that designed to develop the industries of the country. This work is done primarily in the public interest, although it is generally helpful and beneficial to the individual owners.

(To be concluded)

THE ORGANIZATION OF RESEARCH[1]

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I. THE CONCEPTION OF RESEARCH

RESEARCH has been for years past a term with which to conjure, but one to which often only the vaguest and most indefinite meaning has attached. It is frequently used as though it were a sort of trade name, a label wherewith to mark goods of a certain merchantable character. In point of fact there are at least as many types of research as there are research men—indeed probably more. Research may be good, bad, or indifferent; it may be thorough or careless, fundamental or accessory, substantial or superficial, and while certain of these distinctions are too obvious to be labored, there are others which deserve a word of comment.

A distinction often drawn, and having a certain practical validity, is that between research in pure science and research in applied science. It is easy to magnify this distinction quite out of proportion to the actual facts. The objects of research in pure science and the motives inspiring the work may be appreciably different from those encountered in the field of applied science. But the technique of the procedure in the two cases may be all but indistinguishable and either variety of research, if it is to survive the test of scientific criticism, must be based upon absolutely fundamental scientific principles. In the last analysis, the difference reduces almost wholly to the psychological question of motivation. The man working in the field of applied science has before him a concrete specific issue involving some immediate practical exigency. The worker in pure science has quite as definite a specific problem, but it is not one which has arisen out of, nor which necessarily exists in obvious relation to, an immediate demand. Beyond this I doubt if significant differences exist.

[1] Delivered before the Association of American Universities, Columbus, November 8, 1919.

Another distinction which is of great consequence for the development of research consists in the origination of new methods, as distinguished from the application of old methods in a new field. From the point of view of the value of the results obtained the difference is not always of marked importance, for it not infrequently happens that discoveries of crucial significance come out of the application of an accepted technique. But it is perfectly clear that we can make use of a distinctly less fertile and ingenious type of mind to carry forward the application of a method in fields slightly different from those in which it has been previously used than is required for the discovery of new basic principles and the invention of fundamentally new methods. For example, the discovery of the Roentgen rays is an achievement of a very different order from the devising of some new medical use of them, and yet the latter may be popularly adjudged the matter of prime human significance. Every university man is familiar with the phenomenon of a series of doctor's theses, each carrying out in a slightly different range—let us say in a series of biological species—methods devised perhaps by a professor in charge and by him tried out in a few groups to start with. Such work is accepted as original research and unquestionably has a measure of originality, inasmuch as there are almost invariably some new and unexpected conditions to be met which require modifications of greater or less degree in the application of the method. But original research in the largest and most generous sense of the term such work is not.

I venture to draw attention to the issue because research is commonly identified with marked originality, as though the two things were intrinsically synonymous. In the case of the most important research no doubt this is substantially true, but such research shades off through indistinguishable gradations to a form in which the element of originality is reduced to the vanishing-point. It would be a fundamentally wrong inference to assume that because the originality is small therefore the results which may be gained are of little value and that research of this character is to be discountenanced. The fact is that research work is capable of being organized in ways not wholly dissimilar to the organization of our great industries and as such is capable of appropriating and controlling intellectual capacities of the most varied kind.

I would accordingly urge that in our conception of research we look beyond the peculiar combination of intellectual traits, which may characterize any one individual, and think of it as

the organized technique of science itself for its own propagation. It is, so to speak, the reproductive process of science. When thus conceived it takes on a far larger and more momentous aspect than when thought of, as too often at present, as being a mere appendix to the process of science, a sort of luxury of the scientific idle rich. Such a conception is false in practically every essential particular, and yet it is not infrequently encountered in acadamic circles, especially where the traditional humanistic interests are exclusively cultivated.

II. Distribution of Research Functions

At no point in the present administration of research interests in educational institutions is there perhaps more need for searching analysis of present practises than in the methods, or lack of methods, whereby particular lines of research are undertaken. Almost every great university is put in the position of attempting to foster all the major fields of research and an unlimited number of accessory ones. Local pride has repeatedly led to the effort to develop forms of research which may be intrinsically of minor consequence and altogether anomalous in the regions where they are undertaken. State institutions are constantly subjected to pressure of this character, leading to the formation of new departments, some of which have no substantial justification beyond the gratification of the ambition of some energetic professor or some small group whose interests will theoretically be promoted in this way. There exists at present no adequate device by which an indefinite continuation of these conditions may be avoided. Indeed, it is but quite recently that there has grown up any considerable body of opinion recognizing the wastefulness of the present practises. It is of course a matter of the utmost delicacy, and one calling for great breadth of knowledge and great sanity of judgment, to attempt in any fashion to allocate responsibility for particular kinds of research. At the very outset one is met with the contention that any such artificial distribution of functions would operate seriously to cripple individual initiative. And yet the contrary consideration is quite as urgent. To equip every university in the country to carry on research in agriculture, in forestry, in all the branches of engineering, and, for that matter, in all the physical, chemical, and biological sciences, would obviously be wasteful of equipment and physical resources, and all but impossible of execution in the matter of personnel. Certain rough lines of

division are in point of fact at present operative. Some institutions by mere virtue of the fact that they secured an early occupancy of a field have developed to a considerable degree of advancement research work in special directions which might perhaps have been more advantageously developed elsewhere. But meantime, being in possession of the property, it would be ill-advised to attempt to dispossess them. In any event while it is futile, and were it not futile it would be unwise, to attempt any arbitrary and coercive methods in the solution of this general problem, it is not too much to hope that by intelligent voluntary cooperation something may be done to safeguard the situation against an indefinite continuation of the present condition. Through the generosity of the General Education Board, the Education Division of the National Research Council is undertaking a careful study of the actual research facilities of the educational institutions in the country. Some illumination will certainly come from this analysis.

III. Personnel

One of the first prerequisites for a satisfactory adjustment of the present complications is to be found in improved methods for the stimulation and selection of research men. There is a considerable public opinion suspicious of the utility of a great deal of the research which has been fostered by the government and by educational institutions. It is a conservative assertion to say that this opinion has a substantial basis in fact and that an appreciable part of the output of scientific research in any given year is of very trifling value from the point of view of either its immediate or its remote implications. But, as in most human processes, in order to make sure of the essential nucleus of valuable research material, we must probably encourage a considerably larger amount of productive effort than we can expect to realize upon at all completely. One hundred per cent. efficiency in such matters is not to be expected. Nevertheless, there is every reason to believe that we can materially improve the present methods of selection for research careers, and this in two directions: first, by discouraging the unfit, the second, by giving far more encouragement to those possessing the necessary native endowment.

In educational institutions, from which come by far the larger number of research men, it should be possible to establish filtration methods which will eliminate candidates for research careers who give too little promise of success. At the

present time the opportunity to carry on research is almost wholly dependent upon the moral and social initiative of the individual rather than upon his sheer intellectual endowment. If he be sufficiently persistent, he may secure opportunity to be free from portions of his other academic duties in order to prosecute research. And let no one underestimate tenacity of purpose in a research career, but it is not the only desideratum. I have no panacea to offer for the control of research privileges, but I should suggest that a more careful scrutiny, either by research committees or by directors of research, would assure a more promising allotment of opportunity and leisure than now exists. No doubt a practical distinction must be made at this point between the graduate student and the instructor. Both should be called on to justify their opportunities for large freedom in research, but the methods for handling the two cases would differ materially. I recognize at this point the danger of arbitrary discrimination, but I doubt whether it is of serious moment. Far more important, in any case, is the encouragement of the unequivocally gifted research man. This encouragement should be in part in the form of public recognition, both inside and outside the academic circle, and in part should take the form of increased opportunity for productive work. The National Research Council is at present, through the generosity of the Rockefeller Foundation, making an interesting experiment of this kind in the field of physics and chemistry by offering to a group of men, who have already demonstrated their capacity, an opportunity to give their entire time and attention through several consecutive years to uninterrupted research. It is confidently believed that this device will gradually produce a group of research men of the highest quality whose worth will in this apprentice period have been indubitably establish. If the experiment succeeds—and a similar procedure which has been in operation in England for a number of years gives every reason for optimistic prediction—there is no reason why the same principle should not be applied in other ranges of science. The research man deserves a living wage, public recognition of the unique contribution which he makes to social progress, and the best of opportunities for capitalizing his talents for scientific discovery.

In certain universities, if one may trust current report, there is crying need for the creation of a "research atmosphere," with all that it involves of appreciation for the peculiar requirements of the investigator. To plead for this argues

no callous disregard of the obligation to give instruction, but it does betoken the fundamental faith in research as the fountain head of creative intelligence, without which all education must become sterile. The solution of the problem will vary from institution to institution. In some, research committees, if energetic and patient, can produce admirable results. In others, different devices may be preferable. But the research man must ask if he expects to receive.

IV. Training Research Men

Never before has the outlook been so grave for the procurement and training of the required number of research men. Stimulated in large measure by the experiences of the war, the great industries, to say nothing of commercial concerns of all kinds, are calling for expert scientific men often to carry on explicitly research forms of work, in numbers quite exceeding the present available supply. They have been raiding college faculties in a fashion only too well understood by this group present here to-day. Each one of us can count a score or more of men among our colleagues who have been tempted away from the high thinking and distressingly plain living of the academic life to accept a competency, and often much more, at the hands of the industries. The tragic part of this transaction is not that the fine gold of academic self-denial is thus transformed into a baser social metal—regarding this aspect of the case most of use, if not envious, would at least be complacently indifferent—but that by the removal of such men from the universities these institutions, in which at present alone are to be found proper conditions for the training of scientific research men, are seriously crippled, with little or no possibility of making good with any promptness the damage thus done.

One can perhaps hardly blame the leaders of the industries for taking good men wherever they can find them, and in view of the low estimate in which college and university men have generally been held by the great lords of business and industry there is some poetic justice in seeing them obliged to provide themselves at a critical stage of their development with a personnel largely selected from among these previously despised members of the community. But the suicidal character of this policy, if carried forward without modification, is too obvious to require comment. It is surely a short-sighted policy, against which the experiences of the war give every necessary warning, to use up at one fell swoop all, or any large part of, the national resources for producing a trained personnel. Yet this is exactly what is now going on.

Stripped of its equivocations and apologetics, what the case amounts to is that the universities must by one means or another be enabled to pay such salaries to their scientific men and give them such conditions of work as will constitute an adequate offset to the temptations offered by business and industrial life. It is known that we desire to encourage the introduction of the highest type of scientific talent wherever it can be used in commerce and the industries, but as a national program it is our solemn duty to draw public attention to the ultimate price we shall pay if we continue the present process. This price will unquestionably be no less than national scientific bankruptcy with the inevitable reflex of this in an ineffective scientific equipment of the industries themselves. Nations which guide their affairs more sanely in this particular will certainly outstrip us. If the industries are going to rehabilitate themselves in any large degree through improved scientific methods—and this seems to be what the immediate future has in store—they must be brought to appreciate that either through governmental intervention, or through their own direct contributions, the universities must be kept at a high level of efficiency in the training which they give to young scientists.

In my judgment this particular association can hardly do any one thing more useful for the safeguarding and developing of research interests than by setting its face energetically to nation-wide propaganda for the speedy betterment of the conditions of research workers and the trainers of research workers in universities.

In the minds of most college and university authorities there seems to be little or no question that the ordinary work of instruction should go forward side by side with training in research and with the actual research work of the scholar in charge. To this view, however, there are not a few vigorous dissenters. They urge that the conjoining of teaching and research in American institutions is more or less of a national accident and that there is no necessary connection between the two. They insist, and with much force, that to expect a man to do good research who is obliged to teach several hours a day, or even every other day, is in many kinds of research work to expect the impossible. A man needs not only the uninterrupted concentration of attention, but in the case of many types of investigation he must literally be personally present, watching and controlling the course of the phenomena which he is studying. It seems more than open to question whether or not universities have as yet experimented with sufficient

boldness and ingenuity in devices to assure research workers time uninterrupted by the routine of instruction. A few so-called research professorships have indeed been established, but these are the exception, and their success is not as yet wholly assured. Is it, however, impracticable to insure to competent research men for some definite amount of time—say, six months in the year, or some other convenient period—complete freedom for research work? In institutions whose schedule permits, some men have been able to free themselves from class-room work for half the week and in this time to achieve a large amount of research. Of course the practical difficulty which the administrative officers are confronted with is the securing of the necessary amount of instruction to care for the unlimited number of students who insist upon besieging our universities. There is in many of these institutions entire willingness to give the research man reasonable opportunities, but there is often the insuperable barrier just referred to.

As is well known, there is also an appreciable body of opinion holding that research work should be organized under the jurisdiction of exclusively research institutes and that it should not be attempted on any large scale in universities. Whatever may be said of the ultimate merits of this position, it represents at the moment a purely academic expression. There are not institutes enough, and there will not be in any near future, to care for even a fraction of the research work which must be done. Moreover, whether the opinion is justified by final experience or not, it is at present unquestionably the view held by the vast majority of academic and scientific men that both instruction and research are in the last analysis benefited by their juxtaposition in one institution. Furthermore, it must not be forgotten that the purely research institution is sterile in the production of trained personnel. It may train a man in its own technique within the field of its own endeavor, but it must receive the recruit from the university already trained in the fundamentals of science, and from no other source can this supply at present be secured. Whether men trained in institutions that themselves do not conduct the highest forms of research are generally likely to become successful investigators in the institutes is a question to which only the most daring would venture an affirmative reply.

V. Organization and Cooperation in Research

It is a not infrequent remark, and one which I believe to be measurably just, that science despite its magnification of

method has never seriously worked out the method of its own organization. For the most part, it has thus far rested on individual initiative and on such loose forms of cooperation as are based upon the magnetic or coercive personality of some one scientific man. Assuredly, no one expects to create a system of scientific progress which will in any sense be independent of the presence of commanding intellects; but it is equally certain that scientific men have as yet achieved only the most elementary beginnings of the organization of scientific interests. Indeed, it has been something of a fetish among scientists that we must rely upon individual inspiration and initiative, and that the individual worker must be safeguarded in every possible way from the corroding influence of administrative organization. It has unfortunately been generally assumed that an organization which interests itself in research will inevitably exercise such a depressive influence on the research worker. This I believe to be essentially untrue in theory, and I am at the moment connected with an organization which is directing all its energies to proving it untrue in fact. No doubt there will always be wide ranges of scientific work where the individual must toil more or less alone, but, on the other hand, no one who has thoughtfully contemplated the conditions under which modern science does its work can have failed to be impressed with the innumerable unimproved opportunities for cooperation.

In the first place, we have, through processes which I need not stop to describe, parceled out the field of knowledge to a great group of sciences, each of which, perhaps not unnaturally, is disposed to claim supreme jurisdiction over its own bit of territory. The world of science has thus come to present somewhat the appearance of an English landscape with its checkerboard effect of small fields set off from one another by high, impenetrable hedges. To one who toils inside such a field, the universe is limited by his own hedgerow, and inside it he desires to be left in peace to cultivate his crop as best may suit him. The parable has of course its element of exaggeration, but it is unfortunately not so much exaggerated as one might wish, and there are not a few scientists whose thought and speech would seem to indicate an amazing lack of appreciation of the intellectual context of their own work.

The actual fact, of course, is that the dividing lines of science are, like the hedgerows, in large measure arbitrary and practical, and consequently subject to persistent modification. Practically speaking, chemistry and physics are profitably con-

ducted as separate sciences, and yet they overlap and impinge upon one another in ways which have already created the border science of physical chemistry. Botany and zoology have similar relationships. Chemistry and physiology are neighbors of the most intimate kind. Psychology and neurology can hardly get along the one without the other, and so it goes. Under the present organization of science—or lack of it—there is no localized responsibility for bringing together in cooperative enterprises research workers occupying fields that are thus convergent or overlapping. There is genuine need for such cooperative work in many different directions, and one of the first obligations of any method adopted to further the general interests of scientific research must be the providing for investigations which shall thus bring together the scientists now occupying neighboring but distinct fields.

Obviously organization in research must involve something substantially different from organization in enterprises of other kinds, for example, war, industry, sport, and exploration. Organization, I take it, looks primarily to the efficient mustering of all the resources available for a given undertaking, and as the ends desired vary, so do the means for their attainment. In war the individuality of the private soldier must be in large measure subordinated to the conceptions of the high command, and while any ideas he may have to offer may theoretically be received, in practise his initiative is reduced close to the zero point through the larger part of his service. Obedience, rather than initiative, is the first military virtue. Similarly in industry, ideas are desired and generally encouraged, but nevertheless in the stress of the day's work each individual workman must play his previously assigned part, play it promptly and without debate, become in short a cog in the great machine; otherwise production is blocked and economic disaster may be the result. Initiative and ingenuity are essential at the top of the organization. Moreover, ideas supplied from workers at any level of the process are welcome in progressive industries, but the actual application of them to the procedure in hand must ordinarily come from above and the individual unit in the machine must function more or less mechanically.

Evidently organization in research calls for quite a different distribution of effort. Individual initiative, resourcefulness, ingenuity, imagination, vision, must be kept at a high pitch all along the line. Here we are not concerned with quantity production of a stereotyped product, of which the hundred thousandth specimen shall exactly resemble the first. On the

contrary, the product is in some sense constantly varied, and unless it prove to be varied, the process has failed of its purpose, has degenerated into mere hack work, or has been based on essentially mistaken principles. On the other hand, the conception not infrequently entertained that the research man is necessarily the genius working in seclusion is essentially untrue to most of the facts. Many a genius works in seclusion and all research men must be free to work undisturbed at the task in hand; but there are many forms of scientific problems, whose solution is essential to the modern world, which are so complex that no one scientist is equipped to deal with them single-handed. Either they must wait for their solution upon the accidental arousal of interest in the appropriate group or there must be some definite purposeful cooperation established. The great fundamental discoveries may perhaps, as a rule, await the wholly spontaneous efforts of the great genius, but many discoveries of the utmost value to humanity have come from the somewhat accidental observations of men of essentially moderate talents. And not only so, but a very large fraction of the progress in our scientific knowledge in the last fifty years has come, not from the work of the occasional genius, but from the hard, persistent, thoughtful investigations of men who would never be classed as geniuses in any ordinary sense, but rather as trained men of large native ability. This group of men is more often than not eager for those forms of contact with other scientific workers which shall enlarge their own outlook upon the problems with which they are engaged and which shall enable them to pursue more effectively their individual researches. For such men betterment of the machinery of scientific cooperation and the dissemination of useful scientific information not only involves no invasion of their individual initiative, but often is the condition of its successful expression.

To put it in slightly different form and at the risk of repetition, one may say that a fairly prevalent conception of research associates it with the somewhat mystical intellectual operations of the genius, or "near-genius," to tamper with which is a kind of profanation. In this view one must simply wait upon the deliverances of fate. To attempt to assist by any devices of organization is futile. As a matter of fact, large areas of the most needed research lie in territory where properly trained men of talent, given proper conditions of work, may produce constantly and in increasing measure results of the utmost consequence. But one of the conditions of maximal efficiency is that they shall work inside the framework of a gen-

eral program in which there is intelligent cooperation in the allocation of the field and in the constant communication of results achieved. Such distribution of responsibility and effort is entirely consonant with the fullest actual initiative which any scientist can desire. No one compels him to investigate where he does not desire so to do, but by a centralized device for planning he can make his effort count for far more than when he works wholly alone. This is as true of the zones of pure science as it is of the regions of applied science where organization is often thought of as less foreign to the ends sought. Indeed in the research laboratories of a few of the great industries such cooperation has produced the most remarkable results.

Even if organization in research meant no more than thoughtful discussion and planning among a group of men engaged in the same lines of work, it would be immensely worth while. For example, here are a dozen forestry experts in position to determine the research problems which shall be first attacked by the staffs of a dozen different organizations. If there be no contact among them, they may all decide to start upon exactly the same problem or upon utterly disconnected problems. Undoubtedly, some excellent result may emerge under such conditions. Yet nothing is more certain than that the energies of the entire company could have been invested to far better purpose with much less of wasted effort had there been intelligent planning before work began. There is abundant practical experience to justify this conclusion. Repeatedly it has occurred that men working in entire ignorance of what others in their field were doing have traversed the same ground and with results which in no wise justified the wasted effort.

But, as a matter of fact, organization in research means much more than this. Many highly important projects, as we have observed before, involve for their execution the converging efforts of men in different fields of science and in applied science in particular. The agencies interested in improvement of methods must at times come together to set in motion the necessary research work, or it will not get done. Furthermore, the technique for the prompt and convenient dissemination of information regarding discoveries in research is at present lamentably imperfect, and we shall never capitalize our scientific energies at anything like their full value until this condition is removed.

As a matter of fact, cooperation in research may be profit-

ably developed, first, as between scientists working upon related problems in the same general field, say, physics; second, as between scientists in different but adjacent fields, *e. g.*, chemistry and biology; third, as between scientists in different countries, where such cooperation is often essential to success; fourth, as between agencies like the industries requiring the benefits of research; fifth, as between organizations, *e. g.*, government bureaus, experiment stations, and universities; and sixth, by improvements in methods of rendering easily accessible information regarding scientific discoveries.

As practical illustrations of the type of thing we have in mind certain of the problems of public health may be mentioned; for example, sewage disposal presents a question in which the organic chemist, the colloid chemist, and the sanitary engineer are all necessarily involved. The National Research Council has secured the services of a very representative committee to study the fundamental problems of food and nutrition, a problem which in this same way represents the combined interests of a considerable group of sciences. The successful solution of the problem can not be reached without the cooperation of men representing these distinct but related fields of science. One of the most promising ranges of contemporary research is in that border-line group of problems in which the biologist, the chemist, and the medical scientist find their interests converging. A physiological chemist, however learned he may be, is compelled to turn from time to time for scientific assistance to one or another specialist in this group of neighboring sciences. Indeed, it is practically impossible to pitch upon any problem in modern life whose complete solution does not involve an appeal to several lines of scientific approach. In certain cases, through more or less happy accident, the required scientific cooperation is easily secured, but in many instances there has been no adequate provision for securing such combined attack.

Again, within the field of any one of the great sciences, there is opportunity for a kind of cooperation in research which has never been undertaken on any large scale and which can, if properly stimulated and guided, produce results of the highest consequence. For example, there is at the present moment being considered by the National Research Council a nationwide investigation of the problem of reforestation such as no extant single agency can hopefully attack. Similarly, it is planned to study the problems of soil fertilizers in different regions of the country by means of coöperative effort in a considerable group of appropriate agencies.

In certain ranges of science there is not only necessity for the cooperation of individual scientists working on different aspects of the same central problem, but there is also need for international cooperation. One only needs to cite such problems as those of astronomy, seismology, meteorology, and terrestrial magnetism to appreciate how essential simultaneous observations at various points of the earth's surface may be. In such cases international cooperation is absolutely indispensable. Nor are the forms of profitable international scientific cooperation in research confined to the spheres of astronomy and the major phenomena of the behavior of the earth's surface. The study of the behavior of plants and animals under certain standard conditions will afford numerous instances in point.

Perhaps the most obvious illustrations of the possibilities of successful cooperative investigation are represented in certain forms of industrial research, where a group of producers come together and establish a research organization, either establishing laboratories of their own for this purpose or utilizing extant laboratories through which they can arrange for the admittance of their investigators. It is of course well understood that certain of the great manufacturing industries, particularly those connected with the development of electricity, have developed laboratories of the most elaborate kind and of a very high degree of efficiency. But the smaller concern can not afford to develop its own scientific staff, and consequently the cooperative device is found to be the best substitute. This process, which has been carried to a considerable development in Great Britain, is being rapidly fostered in this country, and gives promise of extremely valuable results. Several different methods of procedure are feasible, but time will not permit further discussion of the matter here.

Finally, one may mention the types of cooperation in research which may be achieved by the establishment of more intimate contact between the organizations and institutions now actually engaged in such work. As has been already indicated, we have at present, as the main features of our national research equipment, certain of the scientific bureaus of the federal government and the several states, certain large research foundations, including a few of the great museums, a group of research enterprises in the industries, and the research work done in our universities. In each of these, individuals are at work on problems which, so far as is known to the men engaged upon them, are at the moment not under attack elsewhere.

But our present organization is totally devoid of any adequate means for securing information as to the research work at a given time in progress. In consequence, it repeatedly happens that men are found to have been working on common problems, investing time and energy which might have been expended to far better effect could they have been brought in touch with one another and have learned each what the other had to give in the way of knowledge already ascertained. In the case of the industrial laboratory, both the economics and the ethics of the case render it improper that information should be disseminated as to what is being learned. Even scientific men working alone as individuals have oftentimes been extremely jealous of their prerogatives in the matter of priority of scientific discovery, and have treated their work somewhat in the spirit of the trade secret of the industries. But over against this relatively small group there has always been a larger and more open-minded body of scientists eager to learn whatever could be brought to bear upon their own researches and willing and ready to communicate to others whatever they had to offer of worth. Generally speaking, the ethics of scientific research outside the industrial laboratory is rapidly coming to a point which commends and demands publicity. Indeed, it may be said that this condition has already substantially arrived. Men are eager for more prompt and adequate means of publication of scientific work, and one of the crying defects in the scientific situation as a whole, one which is far more serious in some branches of science than in others, is the need, first, for a central clearing-house of information regarding current research work and its status from month to month and year to year; and second, far more complete and more effective modes of publication of scientific results. Publication needs to be more prompt and needs to be accompanied by much more adequate methods of abstracting and indexing than at present are in operation. To these problems, also, the National Research Council, through its Division of Research Information, is turning its hand, and we hope to be able not only to point the way to better conditions, but also to make a substantial beginning in the actual improvement of these conditions. I will not pause to discuss the entire program of this service, but I may simply say in passing that it contemplates catalogues of research laboratories and of current investigations, sources of information, laboratory facilities, catalogues of scientific and technical societies with indexes of foreign reports, and a somewhat detailed program for the improvement of scientific publications, with particular regard to systems of abstracting and indexing.

VI. Organization of National Research Council

To assist in meeting some of the needs of scientific organization in the United States, the National Research Council has been organized. It attempts to achieve in a democracy, and by democratic methods, such a mobilization of the scientific resources of the country as shall permit their most effective use, not only in times of crisis such as war, but also continuously in time of peace. The German government had succeeded under autocratic methods in carrying such organization to a high degree of perfection and had procured the most striking results, not only in the military administration, but also throughout the entire field of industry. Whether we shall be equally successful under the voluntary extra-governmental plan which we are developing remains to be seen. It may, however, be said at the outset that, rightly or wrongly, the opinion of scientific men is substantially unanimous that in our country an enterprise of this character can reach its highest possibilities only when freed from the restraint of government control. This, however, should in no wise be understood as reflecting upon the efficiency of the scientific work carried on by the various departments of the government. It does, however, argue a widespread conviction based on experience that these departments, despite their many great advantages, must of necessity work under limitations of a very definite and often unfortunate kind.

As the first step in securing a democratic foundation, the National Research Council is based upon the election of members by the great scientific societies of the nation, some forty being represented in the present roster with a constituent personnel running up into the thousands. These representatives from the scientific societies are organized in divisions, of which there are seven representing science and technology. Each such division elects a chairman, who becomes a salaried officer of the council, resident in Washington for one year, and in charge, together with an executive committee of his division, of the scientific work to which the division decides to set its hand. Provision is made for a certain number of members of each division to be selected at large, thereby insuring as far as possible the presence of a thoroughly representative scientific group, for it may at times happen that some important scientific interest is by accident omitted in the elections from the societies.

The council has also six so-called general divisions whose officials are appointed by the executive board of the council, and who conduct the work of the divisions much as in the case of the science and technology group. The personnel of these divisions is determined by the executive board, with the exception of a few persons who are ex officio members. These divisions cover foreign relations, the federal government, the states relations, education, industrial relations, and research information. The Government Division has representatives of each of the scientific bureaus of the government, and is intended to foster, so far as possible, cooperation among such bureaus and among the outside scientific agencies working on similar problems. The Foreign Relations Division has to do with foreign scientific societies. An International Research Council was established at Brussels during the past summer and will take the place of the old international associations and unions which, in forms somewhat modified by the war, will comprise the international unions organized under the International Research Council. The States Relations Division concerns itself with the attempt to foster helpful cooperative relations among the scientific bureaus and other scientific organizations of the several states. There appears to be opportunity here for an outside disinterested agency to render very great assistance. The Educational Division has to do with the interests of research in educational institutions in all its aspects. This division is beginning its work by a careful study of the actual facilities for research in our American educational institutions. It is hoped that by bringing together reliable information about these conditions it may be possible to formulate a more effective program for the utilization of such resources as we now enjoy, for the improvement of the same and for the development of a larger number of better-trained research men. Any rational adjustment of the program of research development in our universities, such as was referred to earlier in this paper, involves a careful preliminary scrutiny of the extant situation. There are some types of research work whose development can be justified only at a limited number of institutions. To have a great group of universities each attempting to do such work is wasteful of personnel and material resources alike. We shall hardly, however, be able to move on to a saner distribution of scientific effort until we know more precisely what are the actual facts in the case, much less can we educate public opinion to accept a reasonable distribution of responsibility.

The Research Extension Division has as its work the stimulation of research in the industries. It seeks particularly to bring into contact industrial groups interested in improving their scientific technique, with scientific men and agencies competent to render the necessary assistance.

The Research Information Service involves a program in many ways the most nearly unique which the council has to offer, in its attempt to create mechanisms for giving prompt and accurate information regarding, not only the finished products of research of all kinds and in all parts of the world, but also the conditions in current research. Its general intentions have already been briefly described and need not be repeated.

Taken in its entirety the work of the council is to be understood as primarily one of stimulation of research in both pure and applied science, and in the creation of an enlarged and better-trained research personnel, with particular emphasis upon the securing of cooperation wherever this can be profitably accomplished—cooperation as described above among scientists in the same field working on different aspects of a common problem; cooperation among scientists in different fields, whether at home or abroad, studying a group of related problems; cooperation among research organizations; and, finally, cooperation among agencies which require the services of research men and research organizations.

The council is itself frankly a piece of research, a great experiment, whose outcome we await with undisguised interest. Its purposes are worthy beyond question. If its methods be unsound, better ones must and will be devised. Meantime it invites your sympathetic support and offers you whatever service it can render.

AGASSIZ'S ESSAY ON CLASSIFICATION FIFTY YEARS AFTER[1]

By EUGENE R. CORSON, M.D.
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It is well occasionally to go back to the old books. A different style, a use of words which have changed their meaning, a different atmosphere, in a way, carry you back at once, and you find yourself in new touch with the subject, but with the many advantages which the newer knowledge and the larger horizon have brought to bear. The original power is there still, as attracting, as compelling as ever: that can never change or fade, no matter what the mere information conveyed may be. But the real searcher will always find the information. The world seems ever ready to forget all but sharp and bare outlines, yet it is often the apparently minor details, slightly noticed at the time and quickly forgotten, which are the real treasure trove. I have found this to be the case in medicine even, where the changes and the new ideas are running ahead pell-mell.

Nearly fifty years ago when a student of zoology and comparative anatomy, I read Agassiz's "Essay on Classification." I can remember the pleasure it gave me, in spite of the fact that the entire scientific world was under the spell of Darwin, Huxley, Tyndall and Spencer, in England, and Haeckel in Germany. To me the book was a great book, no matter what ideas the author entertained of the Creation.

Evolution was the watchword; matter and force, *Kraft und Stoff*, seemed quite wholly to satisfy the scientific mind, even with its ignorance of what matter and force really were. Tyndall gave expression to the prevailing thought at the time in his Belfast address before the British Association. In a sentence long remembered, he declared:

> By a necessity engendered and justified by science, I cross the boundary of the experimental evidence, and discern in that Matter, which we

[1] "An Essay on Classification." By Louis Agassiz, London, 1859. As stated in the preface, dated December 2, 1858, this essay first appeared as an introduction to a much larger work entitled, "Contributions to the Natural History of the United States." Three volumes, quarto. Two volumes had already appeared and the third volume was in the press.

in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with Opprobrium, the promise and potency of all terrestrial Life.

Examined in the light of to-day the words seem to have lost much of their force and meaning: the sentence sounds grandiloquent and has lost its sting. Remember at the time it caused a great cry of indignation from both England and America, veritable hornet's nests of criticism. Its materialism seems very mild now. As a matter of fact there can be no terrestrial life without the promise and potency of matter, whatever way you look at it. The uncalled-for assumption that the world covered matter with opprobrium still further weakens it. The world was quite well satisfied with matter, too well satisfied, perhaps; it was a glorious thing, with a glory of its own, only, as many great souls thought, there was a greater glory back of it. I really believe Tyndall thought so too, only he was just fooling himself! Certainly his materialism could not be compared with the lifeless and soulless "monism" of the German.

Agassiz's students and admirers, while speaking in glowing terms of the great naturalist, his learning and scholarship, his enthusiasm, his wonderful knowledge of animal life, the intensity of his devotion to his work, yet deplored his refusal to accept the Darwinian theory as then set forth, an evolution of organic forms from the lowest to the highest, under the influence of the physical conditions as we saw them.

Darwin's "Origin of Species" appeared in 1859, an epochal work truly when compared with the previous developments in the natural sciences. It seemed to cut the Gordian knot of the mysteries of Creation. It brought to its support a great host of enthusiastic workers, ever ready to support it and find new proofs of its truth. To the German mind it was both appealing and compelling. It was ranked with Newton's law; it was accepted as explaining the entire scheme of life; the mystery of life itself seemed to disappear under the magic of the new conception.

At the time I read Haeckel's "Die Natürliche Schöpfunggeschichte," and without a question my young mind accepted it. The captivating descriptions of the forms of life and their development carried with them an acceptance of the general reasoning and deductions. The German world of thought and science had fascinated and captivated the rest of the world. Students in every branch of learning were flocking to the German universities. It had become the medical center for all aspiring to the higher medicine; that the German mind was not a creative or even an inventive one, mattered not; that

through its genius for details and acquisition it had accomplished marvels in the physical sciences, but at the expense of the interior divinity, mattered not.

The beauty and wonder of Darwin's works were the careful and minute descriptions and comparisons, and the wealth of illustrations which he brought to bear in support of his thesis, with the theories and deductions much in the background. These he left largely to his followers. If he wanted a controversialist what better one could he find than Huxley. If he wanted the development of the theory on a larger scale, there was Spencer to spread the glad tidings world wide. Certainly he found in Ernst Haeckel the most enthusiastic and compelling follower and advocate who outheroded Herod in the physical aspects of the question. His trumpet blew a reveille then, a trumpet, which to my ears, as I read of his death in the last few days, seemed to be sounding taps. His earlier works and investigations of the lower and lowest forms of life are indeed all-embracing, but his philosophical writings are a hopeless logomachy, leading nowhere, a long trail into the bad lands, with no way out of the desert. There is a monism which is the basis of the Eastern philosophy and which has even found its way into the "De Imitatione Christi,"[2] all-embracing, the fullest expression of Spinoza's immanent God. Haeckel, in his aversion to any Deity, had taken a very small bit of it and called it "monism." The Eastern monist readily accepts the essential unity of the organic and so-called inorganic worlds, but in a vastly different sense from the German's idea. To the former it is all the one manifestation of the universal and divine mind, to the latter his "monism" was but the apotheosis of matter itself, as he saw it and worked in it all his life.

Steeped as he was in his own materialism, he could see no good faith nor sense in those who differed from him and looked beyond. In his "History of Creation" he took occasion to refer to Agassiz's attitude as insincere.

And now as I re-read this essay, I find that my whole mental attitude has changed. Darwin, Huxley and Haeckel fade out in a way and I see a great naturalist, certainly as well equipped as his opponents, as profound, as keen an observer—and whose voluminous works bear witness to his master mind—who has reached conclusions totally different. It is when it comes to the real vital question facing us that these minds differ. Go into the alcove in a great library and take down the works of Agassiz, his "Fossil Fishes," his "Contributions to

[2] Lib. 1, Cap. 3.

the Natural History of the United States," and others too many to mention here, and we know that such a life's work shows not one day wasted.

Haeckel had the advantage of a much longer life, yet he can show no greater industry, nor more accomplished. Haeckel is eager to give the world his philosophy, wretched as it is, offering nothing, not even husks for the swine to eat. Agassiz has no such desire, nor, as he tells us, has he time to be a philosopher outside his special field. His love of nature and of the Divine mind which *he* saw in nature filled his life completely as a naturalist.

This Essay on Classification may well have been placed at the head of the Bridgewater Treatises, but Agassiz could not be limited simply by the adaptation of means to ends, upon which these treatises were based; or the argument derived from the connection of organs and functions, for beyond certain limits it is not even true. A rudimentary and useless organ remains "not for the performance of a function, but with reference to plan." Notice the use of the word "plan" instead of "type," something pre-arranged, and yet a type, too. "So careful of the type she seems." The thought shows a great advance in the knowledge of animal forms over the old knowledge as expressed in the Bridgewater Treatises. While Agassiz sees in the rudimentary and functionless organ a proof of the separate creation of the type, and its careful preservation, Darwin sees an argument for his "descent with modification," and his "principle of successive slight variation."

Admirable as Sir Charles Bell's "Treatise on the Hand" was, both zoology and comparative anatomy had grown since his day, and a greater naturalist had a greater knowledge and a wider horizon before him. This advance was due to the developments in embryology, comparative anatomy and the microscope, and the many new forms of life described by the many workers in the field.

With the purely technical portions of the "Essay" I shall not deal; to the public generally Agassiz's spiritual attitude, his own philosophy of life, and what nature meant to him, is of greater interest, and of greater importance. In section 32 there is a re-capitulation of the entire first chapter, a chapter, by the way, which takes up more than half the book. He gives us here in a clear and emphatic way the reasons for his views, the features of nature as he saw them which compelled him to take the stand he took against a tidal wave of thought which had submerged all branches of science. There were few opposing voices in the universities: while the opposition came

largely from the religious world, there were many who saw no antagonism with religion.

For Agassiz, recognized as a great naturalist, a Harvard professor, a leader in his own field, this opposition showed a courage and an independence which only a great mind could command. In the recapitulation of his argument he gives us thirty-one features of the animal world as he saw it. He could see but one great system with the simultaneous existence of the most diversified types under identical circumstances, and with the repetition of similar types under the most diversified conditions. And there is ever before him this great unity of plan in otherwise highly diversified types, these types showing correspondences or special homologies in details of structure to the most minute peculiarities in animals otherwise entirely disconnected; and again degrees and kinds of relationships which can have no geneological connection. From the standpoint of geology he sees the simultaneous existence in the earliest periods of representatives of all the great types, with gradations based upon complications of structure in animals built upon the same plan. Then there is the distribution of some types over the most extensive surface of the globe with others in limited areas; and again, combinations of these types into provinces of unequal extent, and again, identity of structure in animals otherwise entirely different, yet living within the same geographical areas. He sees wonderful series of special structures in animals widely scattered. He sees relations between the size of animals and their structure and form, and the independence in their size of the mediums in which they live. He dwells at length upon the permanence of specified peculiarities under every variety of external influences during each geological period, as well as at the present age, while at the same time, there is a definite relation of animals to the surrounding world and between individuals of the same species. He shows us that, while animals undergo apparently great changes during their growth, there is always a definite limitation of the range of changes. He sees design in the unequal limitation in the average duration of the lives of individuals of different species, and the return to a definite norm of animals which multiply in various ways.

Agassiz as the geologist was strongly convinced that the records all favored design and mind in the conception of the Creation. He emphasizes the order of succession of the different types of animals and plants characteristic of the different geological epochs, and the localization of some types upon some points of the globe during successive geological periods, as well

as the limitation of closely allied species to different geological periods; and so finally he traces a parallelism between the order of succession of animals and plants in geological times, and the gradation among their living representatives; and again, a parallelism between the order of succession of animals in geological times and the changes their living representatives undergo in their embryological growth; and again, finally, a parallelism between the gradation among animals and the changes they undergo during their growth. He even traces the combination in many extinct types of characters which in later ages appeared disconnected in different types, and the relations between these different series and the geographical distribution.

And finally he sees in the mutual dependence of animals and plants for their maintenance, and the dependence of some animals upon others or upon plants, a definite proof of design and of the divine mind.

All these features he described and elaborated in the preceding corresponding sections dwelling upon the modes of mind which they suggest and characterize—creative, purposeful, prophetic, consecutive, and sustained mind, in conformity with a plan laid out before. To him the creative mind is "independent of the influence of a material world." In mind he sees the mind of a Creator and a God of Love.[8]

And again he sums it up in these words:

> All organized beings exhibit in themselves all those categories of structure and of existence upon which a natural system may be founded, in such a manner that, in tracing it, the human mind is only translating into human language the Divine thoughts expressed in nature in living realities.

Agassiz did not accept the Biblical story of creation, nor that sexual relations determine species. He writes:

> When first created, animals of the same species paired because they were made the one for the other; they did not take one another in order to build up their species, which had full existence before the first individual produced by sexual connection was born (page 253).

And again:

> For my part, I can not conceive how moral philosophers, who urge the unity of Man as one of the fundamental principles of their religion, can at the same time justify the necessity which it involves of a sexual intercourse between the nearest blood relatives of that assumed first and unique

[8] In this contrast of views it should ever be borne in mind that the unbiased reader can not find in the "Origin of Species" any real irreligion or denial of a Creator. The difference lay wholly in creative methods or views of the Godhead.

human family, when such a connection is revolting even to the Savage (page 254).

On the contrary, Agassiz contended that the evidence shows more and more strongly that animals originated in large numbers in disconnected geographical areas. Certainly the assumption of the first appearance of many scattered species involves no greater difficulties than that of the first animals appearing in pairs.

Agassiz constantly contends that what really exists are individuals, not species, a very subtle distinction which is in complete harmony with his conception of the whole animal creation. The study of the individual is the very keynote of nature study. The further we get from the individual, the nearer we come to the abstract. Those who contend that the individual is nothing and the mass everything, forget that zero multiplied by one million equals zero.

All students of zoology should read this essay for its clear and concise descriptions of the natural divisions among animals, namely, species, genera, families, orders, classes and types.

The description and analyses of the development of zoology, and the various systems of classifications, are characterized by a judicious calmness, and a considerate and even generous treatment of views which he could not accept.

Cuvier, who first brought to notice the four great types, and whose vast researches in the entire domain of zoology and paleontology placed these sciences on a permanent foundation, he regarded as the master mind of all the naturalists; he constantly refers to his indebtedness to him; he writes feelingly of his debt to Ignatius Döllinger, in whose home in Munich he spent four years of study; he regarded him as the founder of the modern science of embryology, and whom Pander and K. E. von Baer also acknowledged as their master; from him Agassiz learned the value and the possibilities of embryology, and were he to see to-day the marvelous advances of this science, I doubt if they would exceed his own prophetic vision.

The opponents of Agassiz, however bitter their criticism, could not deny his own equipment for his work either by education or natural ability; his works speak for themselves, and no matter what his individual views and theories may have been, there are the volumes, a storehouse of faithful observations, descriptive, comparative, comprehensive, and illustrated by drawings which have never been excelled, an inspiration for future workers for many, many years to come. There is this resemblance between Agassiz and Darwin, that they were both

absorbed throughout their lives in the study of animal forms and animal life, and that they had little time for theories and philosophies. I doubt if Darwin ever dreamed of the extent to which his followers as well as his critics would go.

Of the many phases of this evolution, of the many conceptions entertained, be it in the religious world, or in the universities, or by the man in the street, it was an evolution on a physical plane wholly, under the influences of the elements, of natural selection, of sexual selection, of a struggle for survival, of a survival of the fittest. To some the most devout. it was not inconsistent with orthodox religion; to many rationalists it was consistent with the highest Theism, witness the fine thinking of John Fiske; to the scientific world in general, and irrespective of any religious aspect, the theory as it stood was a foundation for all future research, a key to unlock many present and future secrets. Indeed its real opponents did not base their opposition on the ground of atheism, but because they thought evolution, as then conceived, to be in complete conflict with the universe as they saw it.

It was natural indeed that Darwin should find a complete acceptance in Germany, that Darwinismus should become a school of philosophy, elaborated and reelaborated with nothing left but *Kraft und Stoff*. And the world at large, fascinated by the marvelous intellectual activity of Germany, its amazing industry in research and the most minute investigation, aided by the most perfectly constructed instruments of observation and precision, should turn towards this great Mecca of science with a beating heart and with all confidence. For those who sought these perfected sciences it was the place to go. But it took the bloodiest war in history to show the world that marvels in the physical sciences, obtained at the expense of the interior divinity, must lead to ruin. We see it in the nation as a whole; we see it even more strikingly in the attitude towards the war of the most prominent scientific men—and even among the clergy—an attitude favoring a policy as cruel, as relentless, as world-destructive, as that of the arrogant and brutalized military class in power. Haeckel in particular showed this spirit; he signed a circular in 1916 demanding the retirement of von Bethmann-Holweg, arraigning him for his attitude of conciliation with England at the beginning of the war, his acceptance of Belgian neutrality, and his opposition to unrestricted submarine warfare. Such an attitude seems well in keeping with his philosophy of life, which saw no other creation but a casual, efficient, inevitable, correlation of cells, starting from the one

cell, whose psychic properties were the beginning of the psychism of man. And after man, what? Nothing, not even darkness visible. Surely this was evolution run riot; it was the old story of giving a beggar a horse to ride to the devil.

Now the greatest wonder of it all is that this evolution of the Western world is but a distorted echo or image of a higher evolution, taught by the East thousands of years ago, an evolution on a spiritual plane which we were to see only in a broken and partly disjointed form on our own plane of matter. But the East which is nothing if it is not logical and philosophical, and which must carry its logic and philosophy even to the Antipodes and to the ends of the worlds, taught an evolution and an involution; that what was evolved must eventually be involved; that the effect must go back to the cause; that cause and effect are really one; that every organic form as we see it has its spiritual prototype, a sort of spiritual blue-print, which must be copied to the minutest of the minutest detail. Though from a different starting point and from a different standpoint, it is the same as the Agassiz idea. This is surely better than the idea of life as a casual concourse of atoms; that out of a mass of vitalized sand and mortar a great living temple can be built up without any prototype or blue-print.

And this higher evolution seems to be in complete accord with the developments in molecular physics, a science which has become a true fairy tale, built up by the imagination of the higher mathematics, and which only the real mathematician may read and enjoy. It teaches an evolution of the elements, but it is on the etheric plane. The atom has become the atom of negative electricity; matter as we see it is a manufactured article, made by some one, and the only One, and made out of the invisible, into which it must eventually go back; that from hydrogen to gold is only many steps; that in the chemical reaction we see only the last step, and that it must take the inner eye to see the first; and that this is not only an idle dream, modern researches into electricity and radiant matter show.

I can not conceive of the universe except in terms of evolution and the figure of the circle. Evolution is everywhere: but it makes a great difference how we view this evolution and the forces or powers at work, whether from an earthly standpoint or from a little back of this earth as we see it. I can conceive of a higher evolution where all the steps or links are perfect, of which we can get but an imperfect expression: and I can easily imagine the two great minds of Agassiz and Darwin brought into accord on a middle ground by this higher evolution.

This evolution Agassiz surely could have accepted. Did he know Emerson well? Emerson could have taught him, Emerson to whom the *Song Celestial* was an open book.

Tyndall, in speaking of Agassiz's opposition to the theory of evolution as then set forth, mentions his visit to Cambridge, and his meeting Agassiz at a dinner party in Brookline, and Agassiz remarking in a sad way:

> I confess that I was not prepared to see this theory received as it has been by the best intellects of our time; its success is greater than I could have thought possible.

But Agassiz stood as adamant. What Agassiz fought, I repeat, was an evolution on our physical plane.

As we look back these fifty years, surely the most wonderful changes have taken place. From Tyndall's day our whole conception of matter has been changed. Then it was indestructible: now we see the same matter resolving into its original invisible substance—the real substance. Then the elements were distinct and absolutely defined: now we know that the alchemists' dream of the transmutation of metals was not entirely an idle dream, however futile their efforts to bring it true.

I believe I am well within the truth when I state that the prevailing ideas on evolution as then taught have also undergone a change: that we are seeing, though perhaps dimly, the possibilities of an evolution just back of matter and life as we see it: that the ether, and spirit in whatever way we may try to conceive it, are the real substance, uninfluenced by cold and heat, and pressure, and all other physical conditions which we see affecting the matter of the laboratory and of the ground we walk upon; and finally, that the subtle changes of organic evolution must also be back of this physical plane, the form and quality of life appearing at that time and place best suited for its functioning. I can not help feeling that Agassiz's heroic stand, even with a Scotch verdict, has been justified by the years which have passed by.

Whether his God was the extracosmic God of orthodox Christianity, or the immanent God of Spinoza, does not especially interest me: his real spiritual attitude he has fully shown.

If Haeckel was right and Agassiz wrong, perish the thought: rather let me live in a fool's paradise along with such a soul as that of Louis Agassiz.

THE PHYSICAL SPENCER. II

By Dr. JAMES FREDERICK ROGERS

NEW HAVEN, CONN.

NOTING his intense self-concern, Comte advised Spencer to marry, believing that sympathetic companionship would have a curative effect. Professor Huxley also advised the same treatment, humorously referring to it as "gyneopathy." Appearances gave the impression that he was in fair health. "Appetite and digestion were both good; and my bodily strength seemingly not less than it had been, as tested by walking, was equal to that of most men who lead town lives. This continued to be my state for many years."

"During my consultation with him, Dr. Ransom advised me never in future to live alone. He thought, and no doubt rightly thought, that my solitary days in lodgings had been largely instrumental in bringing on the physiological disaster which had already cost me so much of life and of work, and was thereafter to cost me far more. Probably he inferred that in the absence of distractions my brain had been active during times which were nominally times of rest; and he doubtless recognized the truth that besides this positive mischief, there had been the negative mischief which lack of society and its enlivenments entails."

Congenially settled, he found himself able to write "at the rate of about a closely written page of post-paper per day, which takes me from two to three hours, and though it usually congests my head more or less before I have got half through, I do not find that I permanently suffer."

"How did I pass my leisure hours? In those days I was not a member of a club; and now that I have been for many years habituated to one, I am at a loss to understand what I did in the latter part of the day. Then, as always after my nervous breakdown, reading, even of the lightest kind, told upon my brain just as much as working. So far as I can remember, a walk into town, half-an-hour at a public news-room, and a walk back served to fill part of the afternoon; and the rest was spent in such miscellaneous ways of killing time as might offer themselves."

"The improvement in health achieved during the season in London, was increased in Scotland by the fresh air, exercise, fishing, and—I was going to say—quiet. But I am arrested by the remembrance that to nervous subjects country places often prove the reverse of quiet. The early chirping of sparrows, and, still worse, the clucking and crowing of fowls, are dreadful inflictions to them. I have often entertained sanguinary feelings towards a vociferous cock, which, after I had passed the first part of the night in tossing from side to side, began crowing just as I was beginning to get a little sleep, and kept me awake during the ensuing hours. At Beoch a droll incident was associated with this experience. My bedroom faced the farm-yard, and to get sufficient air in a small room I had to keep the window partially open. The result was that the early crowing of the cock was a great torment to me. To remedy the evil, the good people shut up the cock in a barn on the opposite side of the yard. But as the bottom of the barn door was worn away and the pavement hollow, the space sufficed both for the light of the dawn to advertise the cock that it was time to begin crowing, and to allow the sound to be heard almost as clearly as before. The device they then hit upon, which proved quite effectual, was to place him under an inverted bucket, and there keep him until I was getting up. It was amusing to observe how, when released, he endeavored to make up for lost time by crowing with immense energy and rapidity."

Writing of his forty-third year, he says, "This season seems to have had no relapse from my ordinary abnormal state of health. Sleeping, now as ever a chief difficulty, had been improved by a course recommended; as witness the following paragraphs.

"I have recently been profiting considerably by the advice of a French physician—a Dr. de Mussy to whom Huxley sent me. He has prescribed frequent warm baths—three or more times in the week, with the view of improving my sleeping. I have decidedly slept the better for them.

"Here let me add, for the instruction of the sleepless, that some years later Mr. de Mussy told me he had modified his opinion respecting the efficacy of warm baths as soporifics; for he had met with cases in which, though taken at a temperature below blood heat (as they should always be), they produced wakefulness instead of sleepiness. That under some conditions they do this, I can myself testify; for, many years after, owing I suppose to some change in my constitutional

state, this reverse effect was produced upon me, so that I dare not take a warm bath late in the day. Unexpected as this experience was, it was congruous with a statement once made to me by the late Dr. Bence Jones respecting other medicinal agents. Speaking of drugs, he said that there is scarcely one which may not under different conditions produce opposite effects. Certainly we have familiar proof that this is the case with alcohol, tea, coffee, tobacco and opium.

"This mention of opium reminds me that I had for some time previously made occasional use of it—commonly under the form of morphia. With me sleep brought sleep and wakefulness was habitually followed by more wakefulness; so that after a series of specially bad nights it had been my practice to break the morbid habit, and re-establish the periodicity of sleep by artificial means. Sometimes it was weeks, sometimes months, before I again had recourse to one or other preparation of opium. That the average result was beneficial is an opinion which I here express, because there is, I think, an undue fear of opium; both in the minds of medical men and in those of men at large. Every medicinal agent is liable to abuse; and when it has been greatly abused there arises a reaction, which goes almost to the extent of forbidding its use. In respect of opium a reaction is needed."

Four years later he attempted to increase his hours of work. "It resulted that beyond my morning's work, continued, when I was well, from 10 till 1, during which interval Mr. Duncan acted as amanuensis, some work of so light a kind that it hardly seemed worthy the name, now filled an hour or two at the end of the day. Though reading had the same effect on me as dictating, and though half an hour over a book in the evening made my ordinarily bad night decidedly worse, yet I hoped that I might listen when read to without suffering from it. It was a foolish hope. Many experiences might have shown me that the effect would be mischievous.

"My nervous affection had been from the beginning of such a nature that disturbance of the cerebral circulation was caused by whatever necessitated persistent mental action, no matter of what kind. Often when at a loss how to pass the time, I have been asked—'Why do you not read a novel?' But the effect of reading a novel is just the same as that of reading a grave book. When at my worst, half a column of a newspaper as surely brings on head-symptoms as do two or three pages of metaphysics. Whatever involves continued attention produces the effect. Dr. Ransom, who had suffered from a similar affec-

tion, told me that he brought on a relapse by too persistently watching, through the microscope, the early changes in the fertilised ova of fishes; and he further told me that disorders akin to his own and to mine, were common in Nottingham among the lace menders—a class of women who, all day long, have the attention strained in looking for, and rectifying, small flaws which have been left by the lace-making machines. Hence I might have known that continuous attention to a reader would have nearly the same result as continuous reading. This presently proved to be the case. My restless nights were very soon made more restless. Without thinking what I was doing I nevertheless persevered; and bye and bye found I had brought about one of my serious relapses.

"I have nothing to remind me of the date, but I imagine that this disaster occurred early in December (1867).

"In a previous chapter I named the fact that I had recourse to morphia when my nights became much worse than usual; and doubtless on this occasion I sought thus to bring on again the periodicity of sleep, which, once broken through for some time, had to be re-established by artificial means.

"And here it occurs to me to describe, for the benefit of those who have not experienced them, some of the effects of morphia on dreams. In me it gives extreme coherence to the ideas evolved. Unlike the actions and events of an ordinary dream, which are linked on by accidental suggestions in such wise that they form a rambling series, the actions and events of a morphia-dream are almost like those of the waking state, in their rationality and orderly connexion. For a long time the thoughts which arise bear a logical relation to some primary thought, and the actions performed continue to be in pursuance of some original intention. Occasionally this trait was so striking that I next morning recorded the dream illustrating it."

To restore his "constitutional equilibrium" he spent five weeks in Italy. An incident of this journey which he relates furnishes ample evidence that, aside from its mental functioning, his bodily machine was capable of great and healthy activity.

A few days after his sixtieth birthday he writes, "My vigour is pretty well shown by the fact that I find myself running upstairs two steps at a time, as I commonly do."

From now on his days were spent, one or two hours in reading and dictating, and the rest in walking, riding, fishing, and in killing time otherwise in the best way to avoid mental

activity. There were ups and downs. At sixty-five, after walking about half a mile, wielding a salmon-rod for a quarter of an hour, and walking home again, he was obliged to spend several days in bed and "there was thus made a further descent to confirmed ill-health and incapacity."

After a change of scene and of company, he was, in three years, able to return to London, "frequented the Athenæum daily for a month, and even got so far as playing a game of billiards. Then, as usual, came a catastrophe; too long and too animated a conversation brought me down with a crack, and I was unable to reach the Athenæum during the remainder of the season."

In the "Reflections" of his Autobiography, written in his seventy-third year, he in a masterly way and thoroughly Spencerian style points out that both the quality and quantity of mental activity depend on the working of the bodily machinery. "It becomes clear" he says after this review, "that mind is as deep as the viscera." He goes on to analyze his own behavior and to account for its quality and quantity as compared with that of his parents on physiological grounds. "One apparent reason" why he had "never shown the unfailing diligence common to them is that the cerebral circulation has, by bodily traits, been throughout life rendered less vigourous than it should be." "It is true that my extraordinary feat in walking when a boy of 13, seems to prove that there was at that time no deficiency in either heart-power or lung-power; and, if we pass over the evidence from thoracic development it might be inferred that the damage done by the enormous overtax on a half-finished body, was the primary cause of this defective function throughout after life. Certainly it seems likely to have been a part cause. Be this as it may, however, there is undeniable evidence that, either from deficient propulsive power or from some chronic constriction of the arterioles, the remoter plexuses of blood vessels everywhere have commonly not been duly charged. Hence a somewhat deficient genesis of energy, or at any rate, a genesis of energy not as great as that displayed by my father."

Speaking of his life work, he says: "Men at large have to pass their days in duties from which they would gladly be excused. Quite different has been my lot; my chief complaint having been that state of brain every day forbade me to continue when I wished to do so. Even taking into account chronic disturbance of health, I have every reason to be satisfied with that which fate has awarded me.

"Moreover these disturbances of health have not been of a kind so difficult to bear as those borne by many who have no compensations for them. They have not entailed on me any positive suffering; unless, indeed, the weariness and irritation of perpetual bad nights come under that name. I have not been subject to much positive pain; less, I think, than most are. And then, during the greater part of the time since my break-down in 1855, the constitutional state, which seems to have become adapted to a small amount of broken sleep, has not been such as to negative many of the pleasures within reach. It is true that, reading to any considerable extent being injurious, light literature has been almost wholly cut off, and restriction of evening excitements has been imperative; but otherwise, up to the age of 62, the deprivations were not great. Only during the last ten years, and especially during the last six years, have I been more and more cut off from most relaxations.

"And here let me exclude some misapprehensions likely to be caused by what has been said above. Naturally it will be inferred that the chronic perturbations of health described, and especially those which of late years have brought me to what may be called an invalid life, must be indicated by an invalid appearance. This is far from being the case. Neither in the lines of the face nor in its colour, is there any such sign of constitutional derangement as would be expected. Contrarywise, I am usually supposed to be about ten years younger than I am. And this anomalous peculiarity conforms to a medical observation which I have seen made, that nervous subjects are generally older than they look."

A living and intimate picture of Spencer is that given by "Two,"—the ladies who served as his housekeepers for eight years—from the completion of his autobiography in 1889 to 1897, when the philosopher had reached the age of seventy-seven.

"At twenty minutes to five he drove rapidly to the door in his carriage—a shabby little victoria—and, stepping quickly out, slowly ascended the steps, leaving the innumerable rugs, cloaks, etc., he had brought with him to follow.

"He shook hands cordially, and then entering the dining room sank in silence into an arm-chair. The silence lasted several seconds, after which he informed us that he had been feeling his pulse! Luckily it had been beating regularly, and conversation, to use the hackneyed phrase, 'became general.'

"But our surprises were not all over. He had, with careful forethought and attention to detail, ordered his supper a week beforehand. It was to consist of eggs, toast, and cocoatina, a simple repast which hardly needed so much warning and preparation. But now, at the last minute, he suggested a grilled whiting, 'only it must *be* a whiting, you know; half the time the fishmongers send a haddock instead.'

"At this prompt and unexpected exhibition of masculine nature our spirits rose. 'Come,' we thought, 'this is more homelike. Philosopher or no no philosopher, at least we feel that we have a man in the house.'"

"He used to return from the club at about nine in the evening, and sit with us for about an hour, and if the conversation proved too trying for him he would produce his ear-stoppers and shut himself off from the world of sound. These ear-stoppers were formed of a band almost semicircular in shape, with a little velvet covered knob at either end, which was pressed by the spring in the band on the flaps over the hole of each ear. Very practical and sensible, no doubt, but irresistibly funny to see, and a ready butt for parody.

"Each evening at ten o'clock punctually he rose, wished us 'good-night,' and went to his room. His oddities extended even to his sleeping arrangements, and as he insisted on his bed being made in a certain fashion of his own, he retired the first evening after his arrival at an earlier hour than was his custom subsequently in order to see that the bed had been prepared for him after the approved plan.

"This was as follows. A hard bolster was placed under the mattress, raising thereby a hump on which the small of his back rested. The clothes had a pleat in them right down the centre, so that they were never strained, but fell in loose folds on either side of him, an arrangement which, though we were assured it was most comfortable and restful, certainly looked peculiarly untidy."

One evening "He went off into a discourse on the subject of dress and on the folly of clothing an exposed part, such as the foot, more lightly than the rest of the body, and held forth in his most serious and emphatic style for several minutes on this important topic!

"It was all done in the most natural way, as if socks were a suitable and interesting subject of conversation in any kind of society.

"On thinking of it now, one is inclined to laugh, but there was no thought of that then, not even when, on his companion

saying she suffered from cold feet, he offered with eagerness to give her some small pairs of his own to wear over her stockings if she didn't mind appearances."

"Hearing by chance that one of us had washed her hair in a fireless room, he promptly sent an order to her to proceed to the study to receive a 'good bullying' from him for being so unwise. The lecture was borne meekly, and so his ascendency over us in these matters was established. He next heard that the delinquent always made a poor breakfast; and using the advantage he had gained, he sternly remarked that he must rule her with a rod of iron, and in future should not inquire 'Good morning. Have you used Pears' soap?'—and here he twinkled and gave a little chuckle—but 'Good morning. Have you made a good breakfast? For eating too little is simply a habit which should be broken as soon as possible, for it is an extremely injurious one.'"

When riding, "he would often pull up his carriage with a stentorian shout of 'stop!' to the coachman, no matter where he might be, whether in a quiet place or in the middle of the business traffic in Regent Street. The carriage was at once brought to a standstill, and silence reigned therein for some few seconds. This, we soon learnt, was in order that he might feel his pulse. If it was regular the drive was continued, if not, and he feared injurious consequences, the order was given to return home."

"It was one of his most striking characteristics that when well he was able totally to ignore the dark cloud of illness, which, always hovering, so constantly descended upon him.

"His energies never flagged when his strength did not desert him, and when he was drawn into public controversies he still showed the vigour of a man in his prime."

"We could always tell when one of his bad bouts commenced, for on those occasions he used to adopt a curious garment he had devised to protect himself from cold with as little exertion in dressing as possible. It was made of a warm, woolly material, and compounded in such a way that he had only to step into it and with one pull was fully clad in boots, trousers, and coat. We used to call this the 'woolly bear'—a name he adopted for it—and when we heard from the housemaid he was clothed in it, it was a warning to us that there was a trying day to be faced. The trouble that caused these bouts lay wholly beyond the power of himself or any member of the household to prevent.

"Public controversies gave him many a sleepless night. Ill-informed newspaper paragraphs upset him more than formerly. Any anxiety too, such as delay in the arrival of his MS., caused remorseless insomnia, and many a weary hour did he pass in bed unable to sleep when he made his attack on Lord Salisbury. He was determined to 'smash' him for his excursions into science, and for this he had to suffer, for he could not get the matter out of his head night or day, and finally he was completely prostrated, and a bad bout of illness followed.

"No words can adequately describe the black pall of depression which then appeared to descend upon Avenue Road. Its dreariness affected every member of the household, and forced the spirits into the lowest depths. One typical November day, when the gloom of the impenetrable fog outside was only equaled by the dreary gloom which prevailed within, M. as usual was sitting in the poor old invalid's bedroom, simply that he might feel the comfort of a human presence near him, for he was too ill for conversation.

"He lay buried in his pillows, and gave no sign of life except an occasional long drawn sigh—almost a groan—which accompanied the rising and falling of his hand, and that spoke far more eloquently than words could have done of the state of hopelessness into which he had sunk. For it was one of his worst days, when his ill-health completely mastered him, and although only of a temporary nature, it was terribly trying for him and very distressing for us.

"Hour after hour crawled by. Darker and darker grew the room as the fog slowly descended like a thick veil before the window.

"Complete silence reigned within. From without could be heard occasionally the far-off scream of the London and North Western Railway whistles, as the trains rushed with a dull roar into the tunnel near Chalk Farm Station.

"At length a belated but prosperous bluebottle, as if in protest at the unusual silence in the room, flew noisily across the prostrate figure in the bed. Its buzzing fussiness was almost startling, breaking so suddenly upon the deathlike stillness, and this led M., who was sitting by the fire, to glance across at it and cry, "You ought to be dead!"

"'Wh-what! *What* did you say?' came in a feebly surprised tone from the pillows, and something very like a weak laugh followed.

"'I said that that vociferous bluebottle ought to be dead; and so it ought at this time of the year,' she replied.

"'I saw no bluebottle,' he went on, and the tone of his voice showed signs of increasing amusement as he continued, But you suddenly looked straight at me and emphatically cried, '*You* ought to be dead!'

"Having made that quite long speech, he broke into low, irresistible laughter! And what a welcome, welcome sound it was, for there could not have been a better sign that he was beginning to mend. It was so, and before the day was over M. ventured, with success—for she was not checked—to tell him of an amusing little incident which she had shortly before experienced.

"She had ever since wanted to tell him, but had not dared embark upon so long a story until that weak laugh gave her, as it were, permission."

It was not until his eighty-second year that it became evident that Spencer was going to pieces both physically and mentally.

In this year Spencer wrote an appendix to his autobiography entitled "Physical Traits and Some Sequences" in which he reviews in detail his physical history.

"Until the time of my nervous breakdown, I had good health. My constitution appears to have been not strong in the sense of possessing overflowing vigour, but strong in the sense of having a good balance. All through life, in late days as in early days, my state of body and mind has been equable. There have never been any bursts of high spirits and times of depression; but there has ever been a flow of energy moderate in amount, but sufficient for the purposes of life.

"One consequence has been that I have preserved down to late life a love of amusements of all kinds. I never fell into that state of indifference which characterizes many. Concerts and theatres continued to be attractions until my broken health forbade attending them; a good drama being to the last, as at first, one of the greatest pleasures which life yields. Certain sports too, as salmon and sea-trout fishing, retained their attraction until my strength failed. To friends who have lost liking for other pursuits than work, I have often insisted that it is a mistake, even from a business point of view, to give up amusements; since, when disturbance of health has made a holiday imperative, there remains no means of passing the time with satisfaction. 'Be a boy as long as you can,' was the

maxim which I reiterated. Games, too, I played as long as physical powers allowed. Above all I continued to enjoy the country; my sojourn in which every summer was looked forward to as the great gratification of the year. How fully I entered into its concomitant pleasures may be judged from the fact that I went picnicking when over eighty.

"Being moderate in amount, my flow of energy was never such as prompted needless activities. There are men whose fulness of life necessitates some kind of action—purposeless action, if no other. This was never so with me. Contrariwise, I tended always to be an idler. Action resulted only under the prompting of a much-desired end, and even then it was with some reluctance that I worked at things needful for achieving the end. . . .

"One of the traits of a constitution which, though not vigorous, was organically good, appears to have been a well-finished development of the structures which arise out of the dermal system. I was thirty-two before I had any sign of decay of teeth. I never had a tooth taken out or stopped. Of the eyes, which are also dermal structures, the like may be said. They have all through life remained strong. Down even to my present age (eighty-two) I read without spectacles; sometimes putting on a pair, but finding the inconvenience such that, on the whole, I prefer to do without them. I may add that I have, until quite recently, rejoiced in a strong light. That dislike to a glare which many people betray, even in their early years, I have rarely if ever felt. The like holds with the ears. Those around me say that my hearing is perfect. Is there any significance in this perfection and long endurance of teeth, eyes, and ears, all of them developed from the dermal layer? The implication seems to be that in the process of development there was no failure of nutrition at the periphery.

"During these later years, when capable of any work, my dictation (according to Mr. Troughton) has amounted sometimes to two periods of ten minutes each during the morning, and sometimes to three. Reading for more than a few minutes at a time is mischievous, and listening to reading has to be restricted to fragments. It has been so even with music. Even so simple a thing as looking at illuminations in monthly magazines is too much for me unless taken in portions. Sometimes things have considerably improved, as at Septon, in 1900, when I could walk about the garden a little; while at other times, as in the spring of 1901 and again during the present autumn (1902) I have been mainly confined to bed, even the

extra effort entailed by reclining on a sofa being too much. To all appearances this state of things will become more pronounced, and infirmities of other kinds, which have during these last years added to my troubles, will make such part of my life as remains still more to be dreaded."

But "feeble and emaciated as his frame now was, he had lost little of that strength of will which had always been a marked trait with him, and both nurses and doctors found him by no means an easy patient to deal with. No less emphatic was the assertion of scepticism in regard to the treatment ordered by the doctor . . . he wanted to know the reason for this, that, and the other mode of treatment recommended."

Save for the attacks of aphasia in 1902 and in the next year, there were no marked symptoms. He continued his correspondence and his interest in public affairs into his eighty-third and last year.

Spencer at no time had the appearance of a confirmed invalid. He was proud of his small hands and in his seventy-eighth year had a plaster cast made of them. He was also somewhat vain of his teeth, but, as Hugh Elliot remarks, it would have been better for him had they been filled. It was foreign to his method of thought to have one extracted, since it would have involved "a subtraction from his own personality."

The trend of events in Spencer's physical history run interestingly parallel to those of his father, even to the extravagant outlay of energy in the long walks of their childhood. His long invalidism was very evidently due to a hereditary weakness in the mental machinery—perhaps an inbred tendency not improved by the fact that the family had for at least two past generations been devoted exclusively to mental pursuits, including the nerveracking business of teaching. Neither his father nor his grandfather did more "day by day, than wield the pen or the pencil, and neither of them was given to sports of any kind."

If one were in search of illustration of the connection between mental activity and physiological processes, and their linking in emotional disturbances, he can find convincing proof in Spencer's daily history. The unconscious working of the mental processes is also finely exemplified, for his work flowed from his pen without need for alteration, until something went wrong with the machinery, the disturbances impressed themselves on consciousness, the "secretion" of thought became painful, and vegetation was the enforced order for the remainder of the twenty-four hours.

If one must have a name for his disease, undoubtedly "neurasthenia" would, in our present state of knowledge, be most fitting, and more fitting than in most cases in which it is applied. There was some nerve weakness, but how or why is beyond our present gross knowledge of pathology. Whatever the lesion, we can be thankful that it did not interfere more with the development of the philosopher's great work, and that it was a stimulus to the production of his essay on "Physical Education."

HOW TO SOLVE THE INDUSTRIAL PROBLEM

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THE industrial problem has been solved by the ants, but it can not be solved by man. Ants are abundantly preserved in Baltic amber, belonging to a period about two million years ago, and it appears that they did then pretty much what they do to-day. Their industrial system is fixed for very long periods of time, without any necessity for progress. It is highly successful; the ants literally own the earth. Ant behavior is dominated by instinct, and ants not only can not go on strike, they can not wish to do so.

During the greater part of man's history, he also was unprogressive. For many centuries he lived in caves, hunting wild animals for food, and clothing himself in their skins. He knew the mammoth, and left us drawings showing its hairy majesty. He had no industrial problem, because he was little socialized, and knew nothing of machinery.

In course of time pictorial writing evolved into written language, with an alphabet. Discoveries and inventions were thus recorded, and the knowledge of them was preserved for posterity. Each generation added its wisdom to that of all previous ones, and progress became normal. No man stood exactly in his father's shoes, he was a little more advanced along the road of human development.

This principle of progress was not properly recognized or accepted for a long while. The rate of change was very uneven, and in some cases quite imperceptible. In religion and philosophy it was customary to refer always to the learning of the ancients, and thought was only subconsciously modified. That it really was affected by experience, in spite of all efforts to keep it static, is shown by the various reforms. The wine was new, and at length the old bottles burst. Even then, there was often a pretense of going back to past ideas, instead of a frank recognition of forward development.

It is a singular thing that systems of ideas ran ahead of their application to practical problems. The thoughts of cave men were embodied in clever drawings, not in inventions. It

is true that the early applications of scientific principles made it possible to build the pyramids, but the early philosophies far transcend any mere utilitarianism. There was a surplus of mental power, which delighted in exercising itself. Because this appeared to be the highest expression of human personality, it came to be held that mere practical purposes were somehow lower and inferior.

Discoveries and inventions emerged, often by a kind of accident. It sometimes seemed that necessity was not so much the mother of invention, as the reverse. All this paralleled in a way the evolution of life in general, which proceeds through the selection of variations which were not purposeful in their origin.

The industrial problem really began when manufacture reached a stage in which two or more had to cooperate to produce. The smith was the type of the original manufacturer, literally the one who made things by hand. His skill was individual, yet even he had to be provided with metal. His magic blade, endowed it seemed with supernatural power, owed its qualities to the invention of steel. It was discovered that coal greatly facilitated the making of metal tools, and this new fuel came into general use in spite of opposition. In those days a prophet, endowed with a knowledge of the future, might have sounded a warning. He might have pointed out that a day would come when through the use of coal mighty machines would be constructed. These would require many men for their manufacture, many others to use them. The mining of coal would become a great industry, requiring hundreds of thousands of men. In these ways great deeds would become possible, but the individual would be submerged in the organization. In a true sense, man would be conquered by machinery, as the Erewhonians in Butler's fanciful story maintained. Could all this have been clearly foreseen, it is conceivable that the people might have acted as the Erewhonians, and destroyed all machines, making it a criminal offense to have one in possession. At the very least, they would have wished to do as William Morris said they must, make a bargain with the machine. It must be frankly recognized that the organization of industry, with all its benefits, is not without inherent disadvantages,—disadvantages which cannot be entirely removed. Personal liberty and initiative are restricted; since many are involved, all must play according to the rules of the game. The great question is, how far is it worth while to go in this direc-

tion? If a nation of people acting cooperatively as a unit could secure abundant wealth for all, would it be worth while?

We object to militarism, not only because it leads to war, but also because it enslaves the people. It reduces the individual as such, to the lowest possible terms, excepting only those in command. Our American boys, while the war was on, took things as they came, with a good heart. But now the war is over, we begin to discover what they thought about a number of things. Most of them seem to definitely object to the militaristic system, as a system. Certain officers may have been stupid or harsh, but that is not the real trouble. The trouble is, that men are deprived of the amount of liberty and the pursuit of happiness to which they feel entitled.

It is easy for the average American to understand this, because with us militarism is after all an exotic affair. It has never become natural for us, as it has for the Germans. But it takes very little intelligence to reason from this example to the conditions in the industrial world. Labor unions complain that if they are denied by injunction the right to strike they are virtually enslaved. In spite of the industrial organization, we have kept up a pretense of perfect liberty to work or not, as one likes. Theoretically, and according to common law, a man may seek employment where and when he pleases, or may refuse it. This alleged fact is constantly cited by those who wish to maintain that our ancient liberties have not been impaired. Practically, however, the working man is in a condition of bondage, sometimes called wage-slavery. He is part of an organization, part of a machine. It is impossible for him to be a really free agent, and his employer is hardly in a better case. This is not hypothetical, it is actually a fact. It necessarily results from the increasing complexity of organization involved in the advance of civilization. Industrial progress moves in this direction, and no thinking person is hardy enough to believe that the current can be reversed. The recent coal strike exposed the actual situation very completely. The affairs of this nation are now so thoroughly integrated that the cessation from work of a very small percentage of men may prove absolutely calamitous, just as if some essential part had been lost out of a machine. The government is practically driven to the position of denying the right to strike in this manner, while all the time making excuses and clinging to the verbal doctrine of liberty. The workers are not slow to perceive the incongruity.

Historians will probably record, in criticism of the present age, that whereas we had been brought by the logic of events to

a certain position, we failed to get our bearings. Failing thus, we were slow to move in the right direction, and our blindness and inertia made death or misery for millions. This seems a harsh criticism, but are we sincerely trying to think out our problems, and act intelligently? Are we even honestly facing the facts? Do we realize that times are changing, and must change, in the nature of things? Are we estimating prosperity in terms of human welfare, or in terms of inanimate dividends? Do we really know or care much about the results of our actions? These are not very original criticisms, but they are pertinent. Perhaps the first great fact we have to face is this—that the organization of human affairs must and should extend not only within the nation, but between the nations. This organization, guided by science and democratically controlled, will enormously increase our power of production and transportation. It will create wealth for all, and do away with many of the worst terrors of disease. It may even improve the human stock, and create a posterity which will look back in amazement to the feeble folk of to-day. Every day opens up some new avenue of advance, reveals some new ray of hope. We are already so accustomed to many facilities our fathers never dreamed of, that we can hardly imagine ourselves without them. We rejoice in these gains, but all the time we are being drawn into a great world game, to be played by world rules, and not as we choose. The League of Nations is simply an attempt to frankly recognize the inevitable. The old liberty of the individualist, in respect to these matters, is departing.

Are we therefore bound by the bonds of a Marxian fatalism—destined to be puppets of a completely socialistic state? The profiteer, the tyrannical capitalist, these are surely mere diseases of the system: but the system itself, when completely democratized, must dominate the individual. We will cure the diseases, but can we alter the patient's constitution?

It seems to me that the dilemma, if fairly faced, might lose most of its terrors. Grant increasing interdependence, and deny the right to strike; what then? First of all, I should say that with modern science, modern machinery, there is no valid reason for not producing all the basic necessities for human welfare. There is no valid reason for not making the hours of labor reasonably short and the conditions healthful. The state, which in the modern sense requires the services of all, is under obligation to attend to these matters. It is the duty of the state to establish a standard of living, and see that all industries reasonably conform to it, in respect to all the workers. The

time has long passed when the individual could do this for himself; it can only be done through community action.

Scientific research into social conditions should become a leading public function, and every industry should be watched, as a captain watches his ship at sea. Real justice should only be limited by ability and the bounty of nature. All this might come about under and through organization; it represents the real advantages of that process. Under such conditions, strikes would appear as meaningless as a refusal to come to meals, and the workers' welfare would be better cared for by experts than it could be through the operations of his will.

Bellamy pictured some such millennium in his "Looking Backward." Morris rebelled, and socialist though he was, would have none of it. He accordingly wrote the charming "News from Nowhere" as an antidote. Most Americans, reading both books, would probably confess a leaning toward the opinions of Morris. We don't want to be bound, even by golden chains, and we are well convinced that the process would endanger what we regard as the highest human attributes. Is there no better way out? It may well come through science and organization itself. The working day, if by that we mean the period of obligatory service, may be reduced to six hours or less. Inventions and improvements are rapidly increasing production per labor hour. Thus through bondage we may win our way to all the liberty we need. Half our active hours may be ours alone, to do as we please within generous limits. In this wide field of opportunity we may develop personality, and enjoy the sense of initiative. From the standpoint of national progress, these may well be the most fruitful hours of our lives, wherein we shall leap boundaries and set new marks. But the pitiful thing is, that we are as yet little fitted for these golden opportunities. Who can say that the free time of most people is well spent? Suppose the nation were put to-morrow on a universal six hour basis, would the result be good? It would in any event be much better than the twelve hours of the steel industry, but how many of us could profitably employ so much freedom from restraint? Idleness is destructive of character, and meaningless occupation is little better. There is actual danger that we may succumb to the effects of habitual constraint, so that we can not use a large margin of liberty.

If the present aims of the working classes are substantially gained, as they surely will be, it will be no small task to realize the full benefits. Educational processes must develop the power to play as well as work, if by play we mean free and

self-directed occupation. Power of initiative must be deliberately cultivated, but also judgment as to when it may be properly employed. If we are successful, we may see within the next hundred years an intellectual and spiritual development far transcending anything yet imagined. Yet this may only be if we have a program, and deliberately set ourselves to realize it.

At that time, the industrial question will have been solved, in so far as we shall have attained an adequate *modus vivendi.* But it will never be solved as it is for the ant, because each generation will face new problems. Human society under the conditions of civilization is dynamic, and its gods may never slumber.

In the new day to come, it may seem probable that the bound time will appear so much less interesting than the free time, that its duties will be shirked. I do not think it will be so, as there will not only be the incentive of public service and universal benefit, but also the joy of *skill.* The things we do many times are those in which we develop skill, and consequently the worker in his bound hours will work efficiently, with relative ease and self-respect. In his free hours he will experiment and blunder, and continually realize his imperfections and limitations. The notable gains of the free hours will far transcend these of the bound, but they will be the survivors among many unsuccessful attempts.

ENGLISH HARBOR[1]

By Professor C. C. NUTTING

STATE UNIVERSITY OF IOWA

SOMETIMES one bores for water and finds oil. Thus a party of naturalists went to the Leeward Islands to study the fauna of coral reefs and happened upon a spot chuck full of romance and overflowing with historic and legendary associations.

Few Americans know that there is an island within 250 miles of American territory where a foreign power has spent something like $125,000,000, in erecting dockyard facilities and fortifications for a great naval base and quarters for a considerable army. Let no one be disturbed, however, when informed that it is all true; for the foreign power is Great Britain, bound to us now by a comradeship that is destined, please God, to endure; and the great naval base is so far forgotten that there are imposing ruins of buildings whose very names and functions are unknown even to local officials.

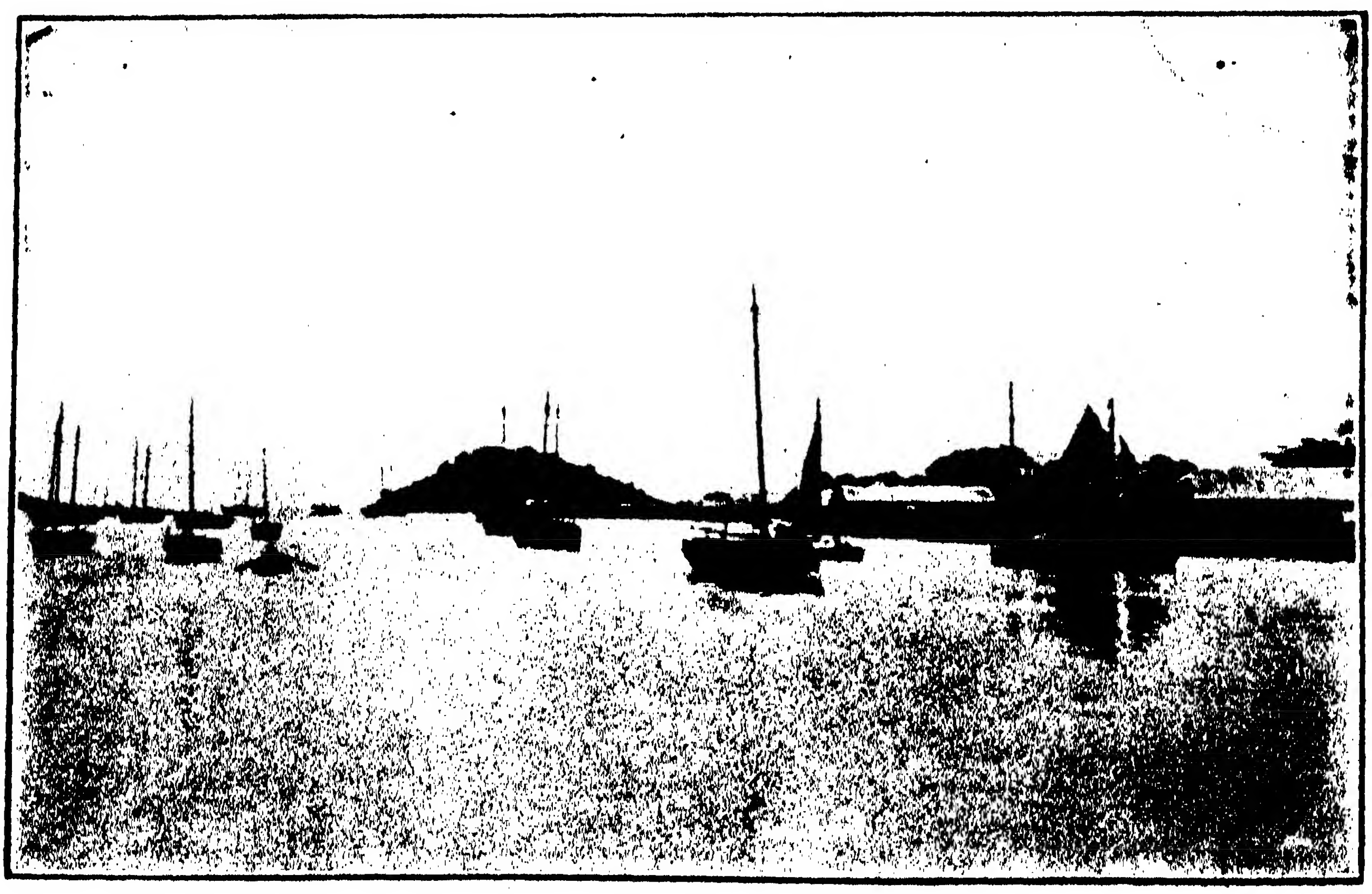


FIG. 1. VIEW IN ST. JOHN'S HARBOR, ANTIGUA.

[1] Photographs by Maurice Ricker.

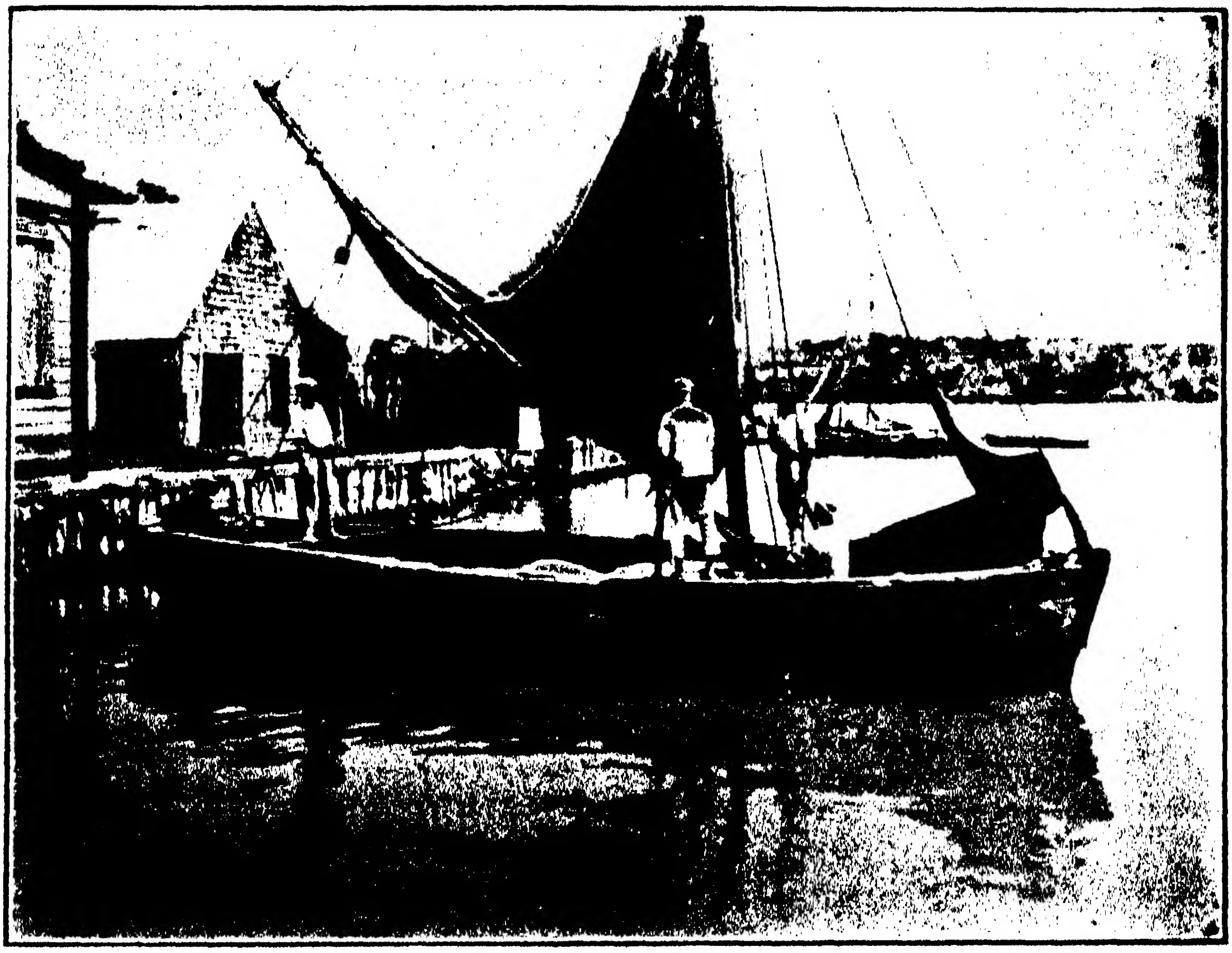


Fig. 2. Native fishing boat, Antigua.

There are few more exciting chapters in the history of the New World than those dealing with the struggle, mainly between Great Britain and France, for the group of islands stretching between Porto Rico on the northwest and Barbados on the southeast; a struggle that at times engaged fleets of considerable size and involved the question of naval supremacy in the Western Hemisphere.

So prolonged and bitter was this contest that Great Britain found it necessary to locate a base of operations in the Lesser Antilles. Good natural harbors are few and far between in these waters. The United States has one now at Charlotte Amalia on the Island of St. Thomas, the French have one at Guadeloupe, the British have one at St. Lucia; and that is about all that are at present available for modern shipping.

But, for the purposes of the naval vessels of a century and a half ago, there was a harbor unsurpassed in natural and strategic advantages. John Bull, with his characteristic long-headedness, was quick to see the value of such a base and Captain Francis Cooper of H. M. S. *Lynn* and Captain Del Garno of H. M. S. *South Sea Castle* "share the credit for calling attention to the great advantages which would accrue from providing a suitable place in the West Indies for careening and refitting ves-

sels, and from thus obviating the need of sending ships all the way to the North American Colonies for the purpose."[1]

The writer's acquaintance with this locality was purely accidental. All he had known of Antigua previous to the summer of 1917 was that it is a speck of an island in the Lesser Antilles. His first impression was conveyed by an officer of the *Quebec* Line to the effect that Antigua is "hotter'n Hell!," which is probably an exaggeration.

FIG. 3. THE GLARING WHITE STREETS OF ST. JOHN'S.

As director of a scientific expedition from the State University of Iowa, the author paid a hurried visit at the suggestion of Sir Francis Watts, Imperial Commissioner of Agriculture for the British West Indies, little thinking that he was destined to spend considerable time at a place of which Aspinall says:

"In the entire chain of West Indian Islands there is no spot at once so romantic and so full of historic interest as English Harbour, which lies at the southeast corner of Antigua, the seat of government of the Leeward Islands."

The only port available for large vessels is in the harbor of St. Johns, a commodious one in point of size; but so shallow that the anchorage is about three miles from town and pas-

[1] Algernon E. Aspinall, "West Indian Tales of Old." The writer is indebted to this work for most of the dates mentioned, although many of the historical facts and legends were learned from various residents on the island and from publications loaned by His Excellency, Governor T. A. V. Best, at that time acting governor of the Leeward Islands.

Fig. 5. Native hut, Antigua.

Fig. 4. Riding donkeys which resemble slightly magnified jack-rabbits.

FIG. 6. WE GLIDE THROUGH A LARGER VILLAGE.

sengers are transferred to a wheezy steam launch that may, or may not, reach the landing without breaking down and drifting about in one of the furious tropical downpours of that region.

The glaring white streets and houses of St. Johns impress one most painfully on landing; but the auto ride through the valleys and over the hills, on excellent roads and with novelty everywhere, atones for the initial discomfort. Our course traverses the central valley that in past times cut the island in two with a stretch of salt water where we now ride. The people, practically all black, are trudging along the road or riding donkeys which resemble slightly magnified jack rabbits.

Later we enter a hilly, indeed almost mountainous, region where we glimpse delightful vistas of little side valleys with hamlets of grass-thatched huts snuggled under cocoanut palms with a goat or two and innumerable pickaninnies naked and unashamed. Now we glide through a larger village, such as Liberta, with the little white Wesleyan Church crowning a hill top, and then we pass a great thicket of thornless cacti, the kind used by Burbank in producing his famous strain which combines the succulent leaves of the prickly pear with the thornlessness of the Antiguan form.

Here we pass a village pump with its group of women, reminding one of Bible scenes, except that here kerosene cans are poised on the heads instead of the graceful water jars of the East; but the women here are just as graceful in their pose as their oriental sisters.

Mounting an unusually high hill we get from its summit a glimpse of the deep blue of Falmouth Harbor, encircled by almost mountainous peaks, reminding one of Swiss Lakes. Here, too, we see over the neck of the "Middle Ground" the yellow buildings of the dockyard at English Harbor, our destination. With honking horn we rush through the remnant of the village of English Harbor, over a mud-flat skirting a mangrove swamp and come to a stop before a solid wooden gate between massive stone pillars. Honking some more for the ancient warder, who hobbles out, salutes and swings the gate on its creaking hinges, we enter the most historic spot in the West Indies.

A gorgeous flamboyant tree shades the caretaker's house on the right as we glide between the "Capstan House" and naval barracks and bring up in front of the great stairway in front of the "officers' quarters," our home for a month of strange and uncommonly interesting experiences.

This building is the most modern of all and replaces a much older one destroyed by the great hurricane of August, 1848. The lower story is occupied by a series of huge tanks containing rain-water, the only water for drinking and laundry purposes available at the dockyard. Above are the living rooms, which furnished space galore for our entire party of nineteen, besides a dining room and kitchen, and spacious verandas in front and rear, stone-flagged and deliciously cool from the constant trade-wind from off the open sea.

On moonlight nights this big veranda was next door to Heaven, with hammock chairs, congenial friends, the glorious

FIG. 7. A CLUMP OF THORNLESS CACTI.

FIG. 8. A VILLAGE PUMP.

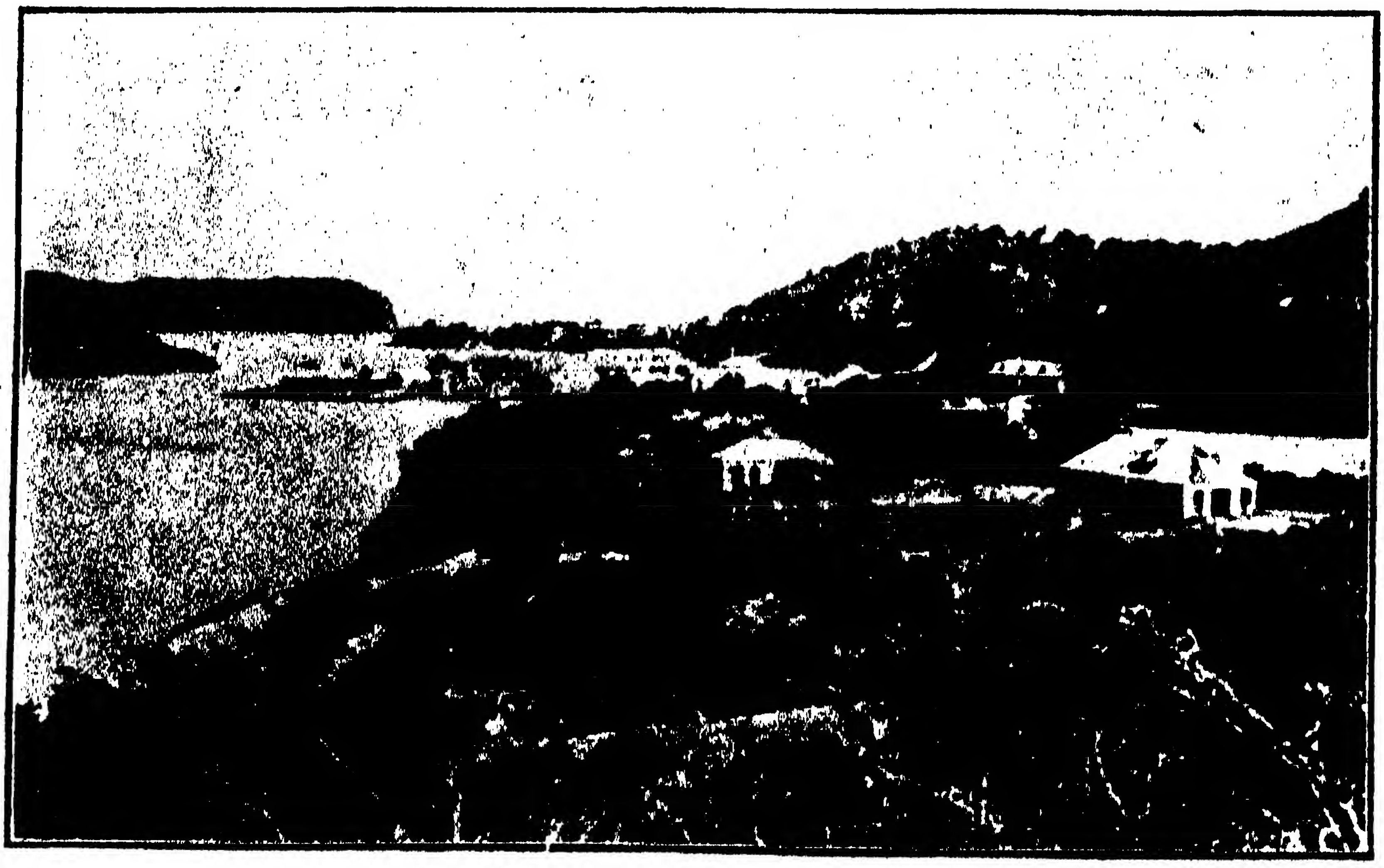


FIG. 9. THE DOCKYARD, ENGLISH HARBOR, IN THE DISTANCE.

shield of the tropic moon creeping over Fort Barclay and reflected in the still waters of the harbor, music from Stoner's mandolin, an evening pipe and the contentment that comes from a hard day's work in a naturalist's paradise. Such a combination makes one realize the worth-whileness of being alive!

And yet this spot was regarded as simply a Hell-hole by the officers of His Majesty's Navy under the conditions existing in 1756, when Captain Edward Thompson wrote:

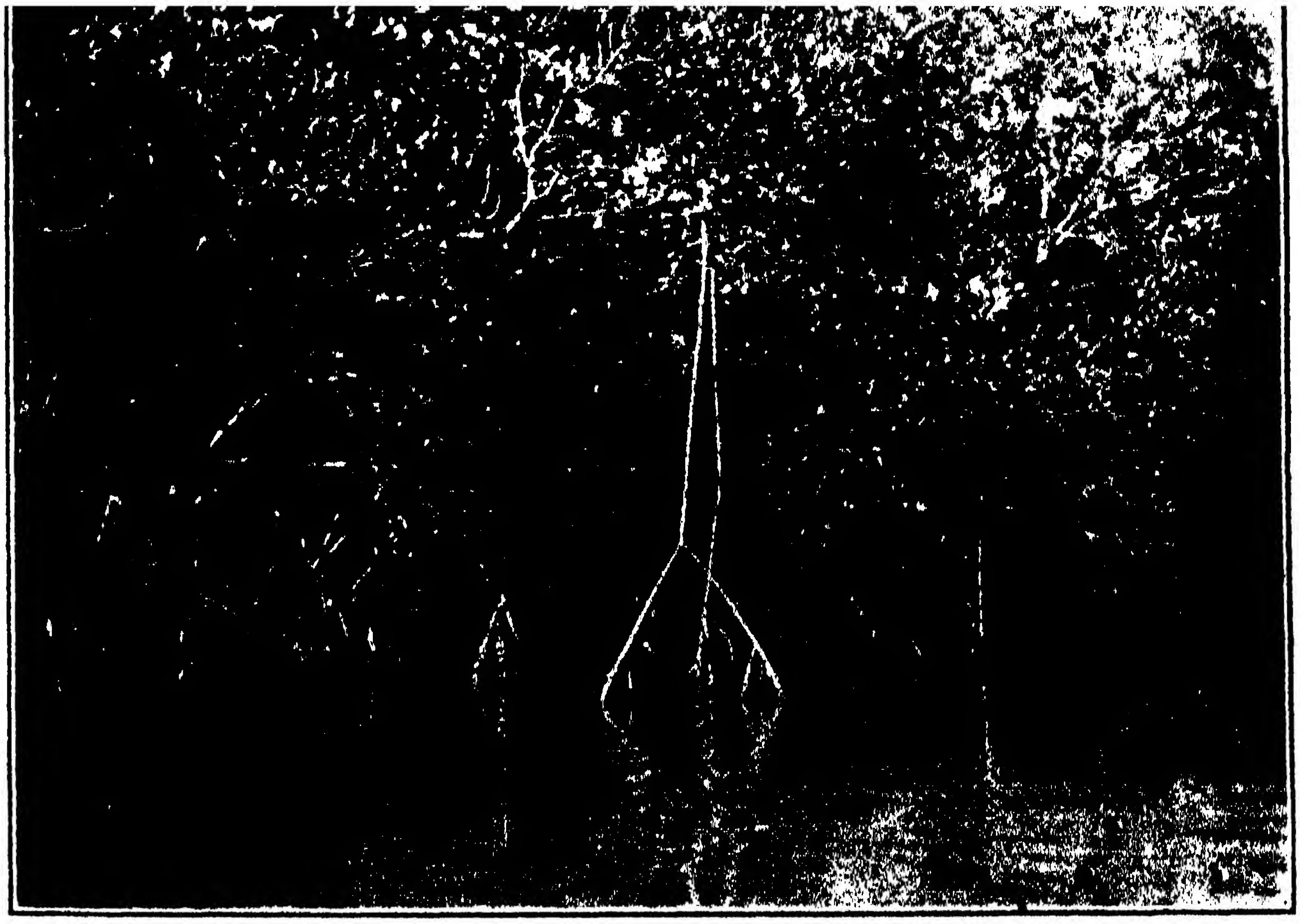


FIG. 10. A MANGROVE SWAMP.

"With the strictest truth I may call this one of the most infernal places on the face of the Globe," and the great Nelson says: "English Harbour I hate the sight of!" and calls it a "vile hole." The ravages of yellow fever in those days were frightful; the *Stegomyia*, a mosquito that now is known to be the carrier of this dreadful pest, being bred in countless swarms in the rain-water tanks and neighboring mangrove swamps. Whole crews of naval vessels were stricken and practically wiped out.

The naval barracks, a brick structure 100 feet square, is still standing and served as our laboratory, though decrepit and leaky. The old "capstan house" contains a cherished relic of the present King George V., which was shown us very reverently by the caretaker as a special favor on the fourth of July.

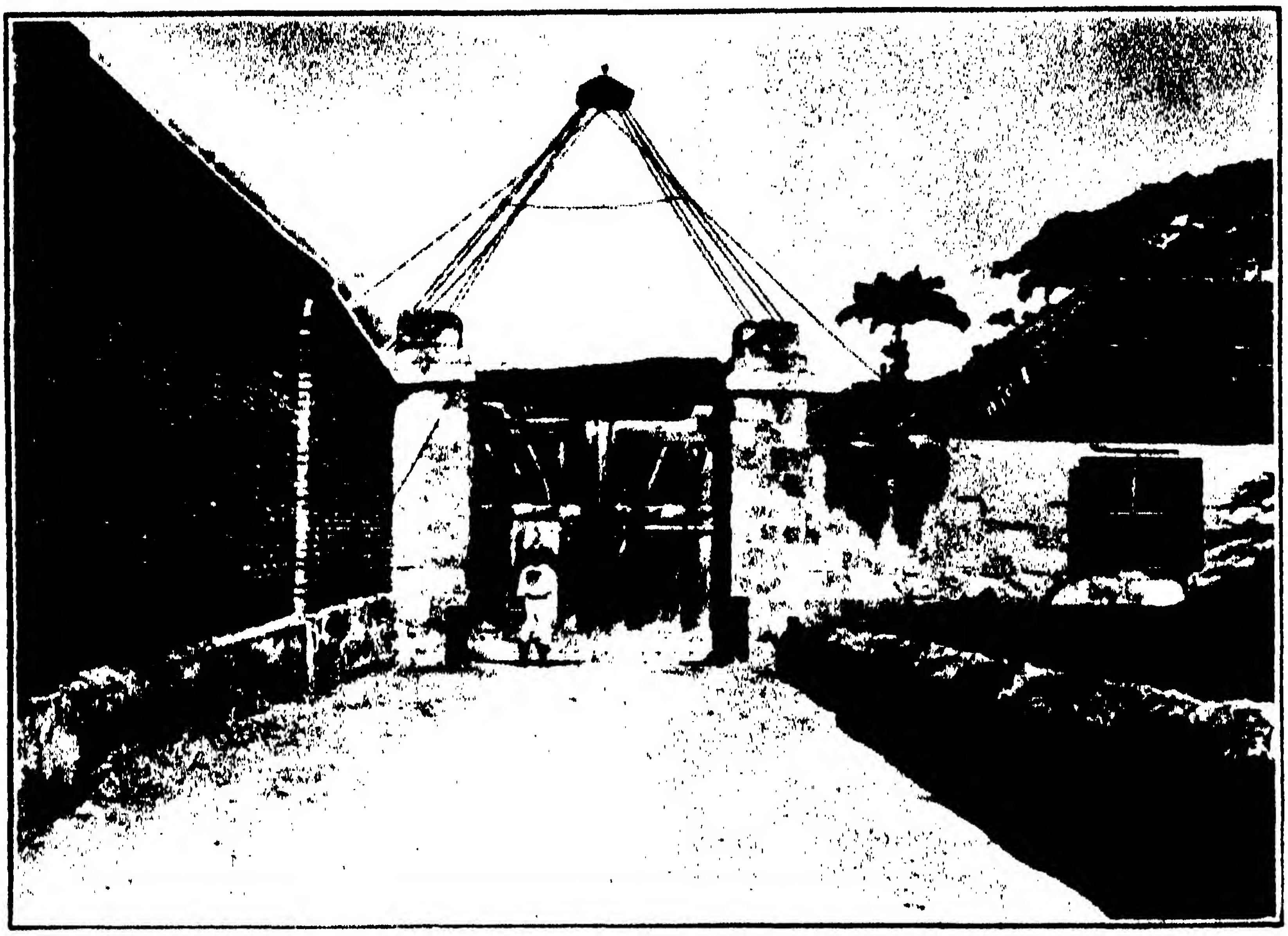


FIG. 11. THE GATE TO THE DOCKYARD.

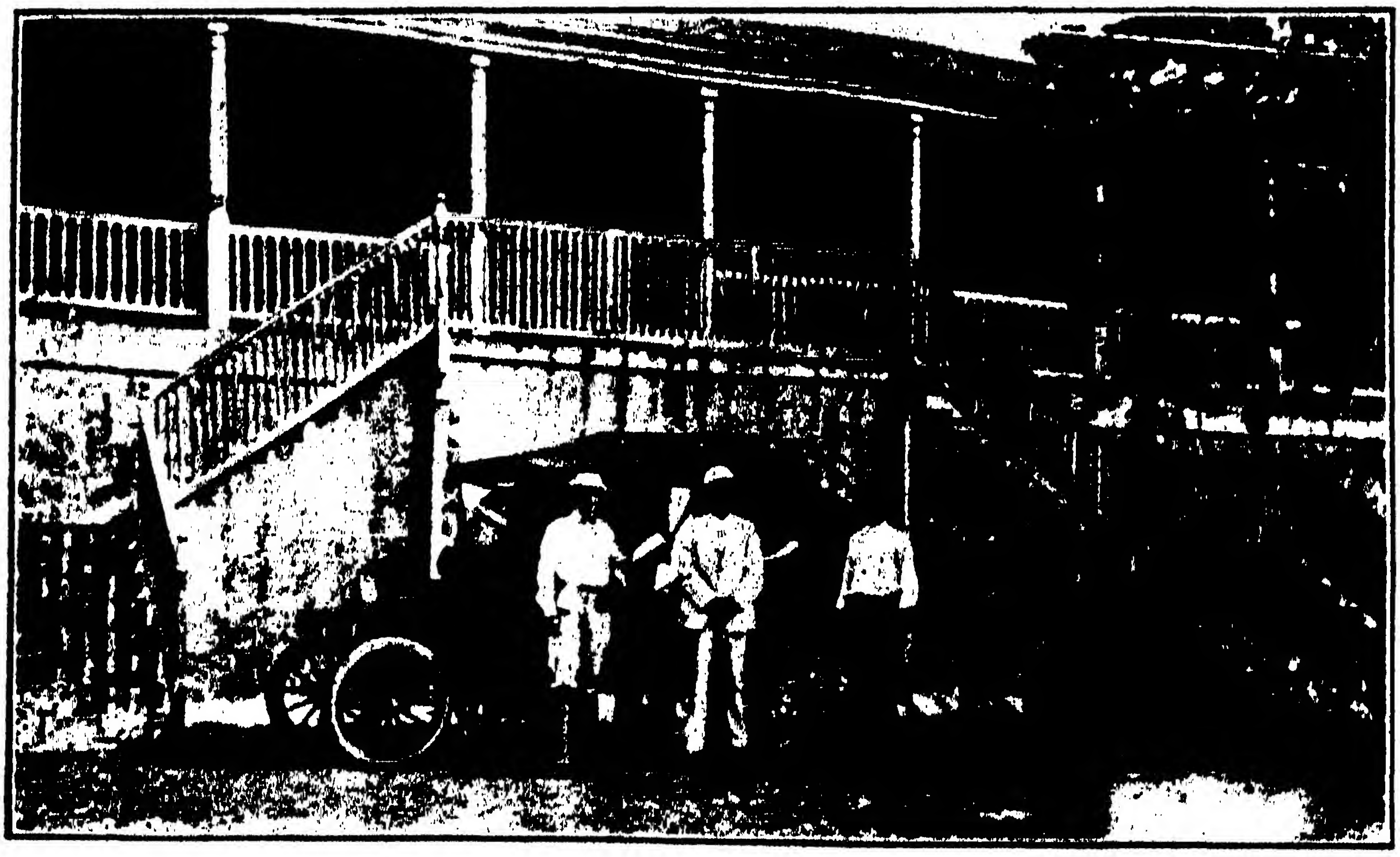


FIG. 12. THE FRONT OF THE OFFICER'S QUARTERS, OCCUPIED BY THE BARBADOS-ANTIGUA EXPEDITION.

It is an inscription supposed to have been made by His Majesty, then on H. M. S. *Canada* on a brick wall and enclosed in a sort of cupboard. It reads: "A Merry Xmas and a Happy New Year 2 you all." We stood with uncovered head and were duly impressed.

There are a number of other buildings in various states of dilapidation. One consists merely of rows of great stone and brick pillars capped with mortar domes; but no one now knows for what purpose it was intended.

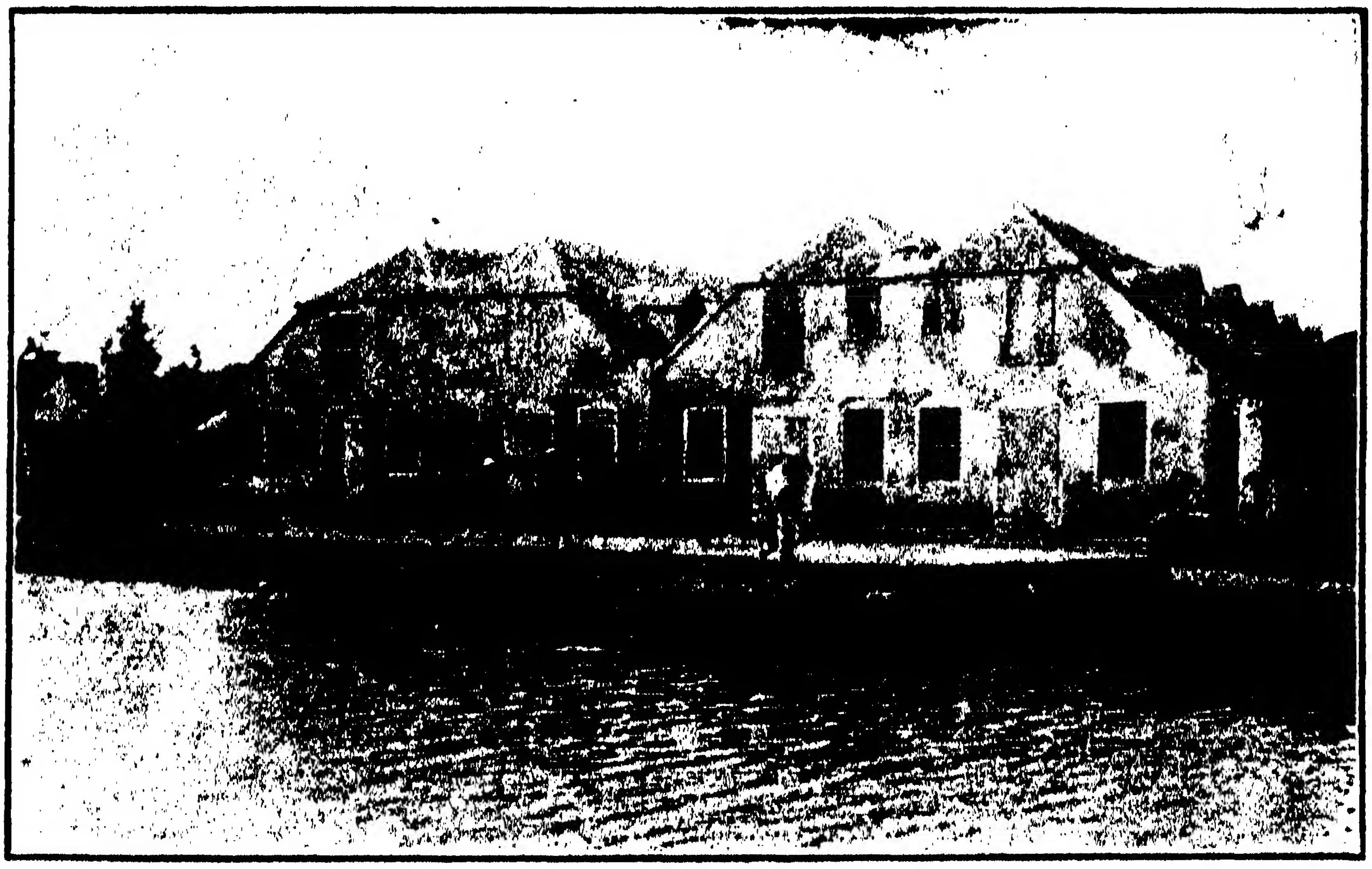


FIG. 13. NAVAL BARRACKS, USED AS A LABORATORY BY THE EXPEDITION.

Standing in the quiet and peaceful scene of the present, it is hard to imagine the place as it was—the bustle and clamor of the dockyard when, especialy during the hurricane season, considerable portions of the Royal Navy put in here to refit.

The clang of hammer and clank of chain, the songs of sailors careening vessels and the picturesque oaths of brawling men reechoed in the turmoil of strenuous activity. It was a time of hard drinking and strenuous profanity. The officers' quarters saw many a wild revel and the requisitions of that day reveal large orders of wines and liquors, and many a son of Briton's nobility gave himself up to unrestrained license. Theatricals and cock-fights, interspersed with drinking bouts, were popular forms of amusement when Prince William Henry visited the place in 1786 and seems to have been a general favorite both with Navy men and the aristocracy among the Colonials of the day.

A large anchor, attached to a massive block of cement, and probably used in careening vessels, marks the place of a tragedy that stirred up quite a commotion at the time. It is known as the Camelford anchor. Lord Camelford of H. M. S. Sloop-of War *Favorite* seems to have been one of the most reckless and fiery tempered of the young officers of that period. A question of seniority arose between him and Lieutenant Patterson and resulted in bitter enmity. A direct issue presented itself when the latter refused to obey a command of Camelford's, who promptly seized a pistol and shot him dead on the spot where the anchor now rests!

FIG. 14. THE KING'S INSCRIPTION.

From the accounts which come down to us this seems to have been a needless murder, and nearly resulted in a mutiny; but Camelford was acquitted by the court martial, only to die later in a duel in which he confessed himself to have been the aggressor.

A sun-dial, set on a column of masonry and enclosed in an iron railing is still remarkably accurate as a timepiece and served us well during our stay.

Looking west across the water from the officers' quarters a hilly promontory is crowned by Fort Barclay which mounted a formidable battery with numerous embrasures for guns, and a solid stone powder house with a roof of heavy masonry. This we decided to use for a refuge in case of a hurricane. Steps cut in the cliff led down to a little landing on the lee side of the promontory, while on the other side the breakers pounded incessantly.

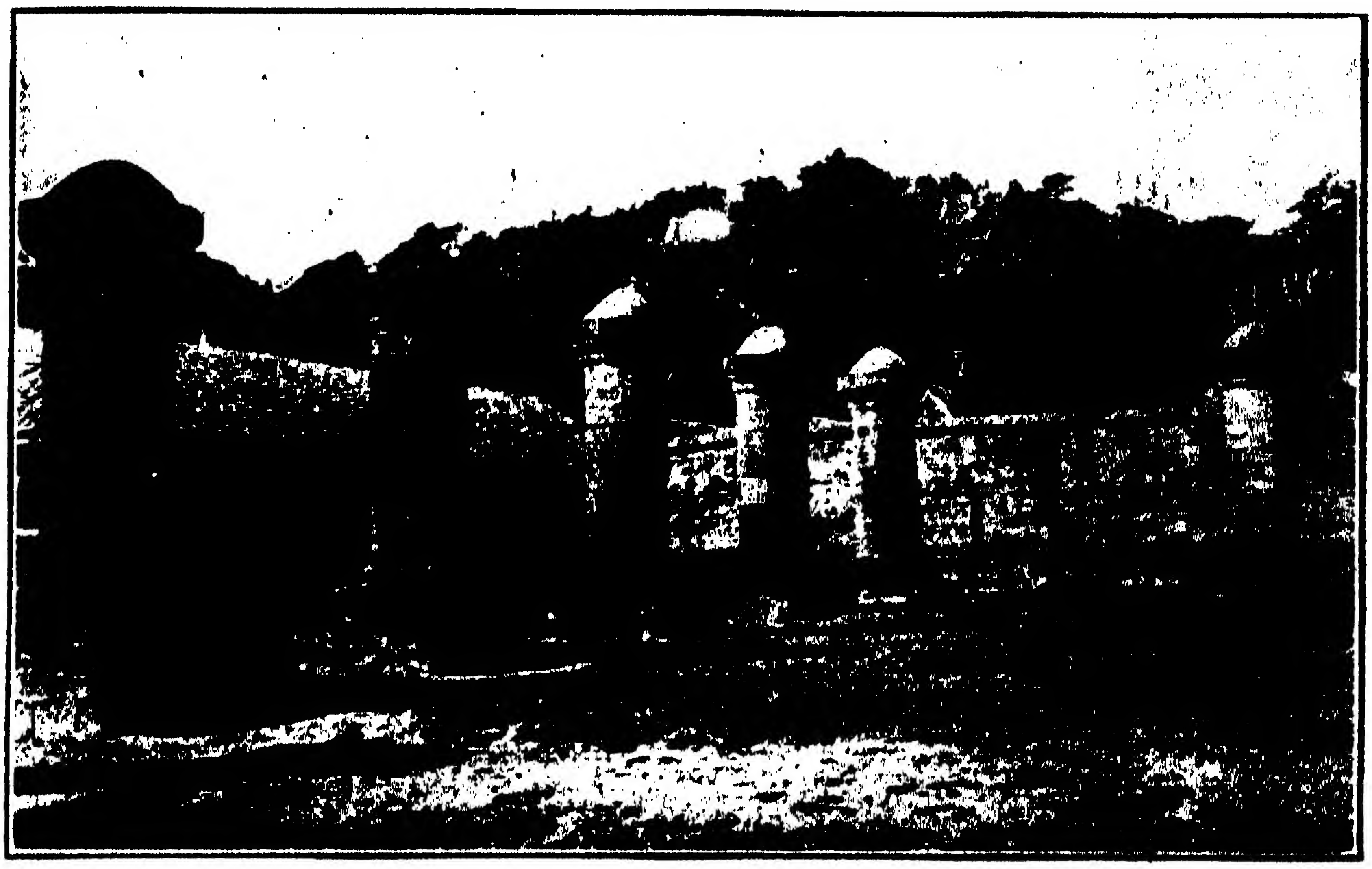


FIG. 15. NO ONE KNOWS THE PURPOSE OF THIS STRUCTURE.

FIG. 16. THE "CAMELFORD ANCHOR" MARKS THE SCENE OF A TRAGEDY.

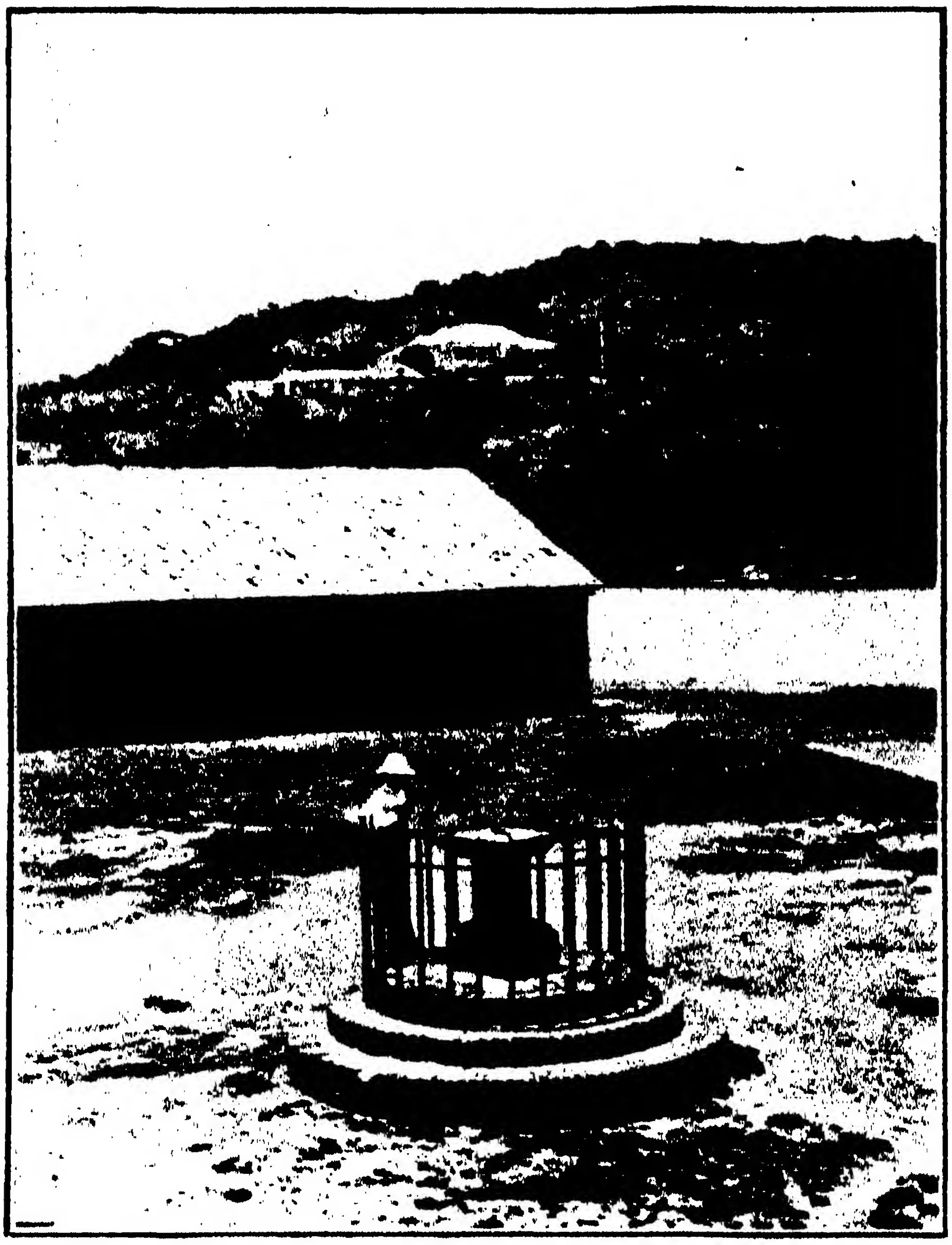


FIG. 17. THE SUN-DIAL IS STILL A REMARKABLY ACCURATE TIME-PIECE.

On another hill to the south of the dockyard the white walls of Clarence House peeped from its shelter among the trees. Originally intended as a residence for the Duke of Clarence, afterwards King William IV., and then as the Admiral's house, it is now occupied as a country house by the Governor of the Leeward Islands, His Excellency, Acting Governor Best, who was our most gracious host on several occasions. At certain times and under favorable conditions the ghost of Lord Nelson is said to appear at Clarence House; but we looked for him in vain, particularly on moonlight nights.

The great Admiral, by the way, detested English Harbor and called it unkind names. This may be due to the fact that he was violently in love at the time of his sojourn there with a charming young widow who lived on the Island of Nevis and afterwards became his wife. Like most sailor-men, Nelson was most ardent in his affections and doubtless chafed and was unusually irritable on account of the enforced separation from the object of his affection. All of which leads us to doubt any inclination to visit English Harbor even in ghostly guise.

A military road of easy gradient leads upward from Clarence House to Shirley Heights, often called "the Ridge." On either side of the road is an impenetrable jungle with many bristling cacti and other thorny plants, among which is the "wait-a-bit," exceedingly well named as its vicious recurved thorns grasp one's clothing with a tenacity which demands pause and elicits fervent profanity from the ungodly as one waits a bit to free himself from the entanglement which grows worse at every movement.

Ruins are everywhere. Here an old gun emplacement and there an ancient dismounted cannon. Here a vault-like powder magazine and there a massive fragment of wall. The remains of a great hospital are now occupied by a few donkeys and goats, and human squatters who come to beg in a mechanical and unenthusiastic manner of the very occasional stranger.

Among the most impressive of these ruins is the old officers' quarters with a long colonnade in front, the imposing arches of which testify to the original massiveness of the building. At one time many thousand British troops were quartered on "the ridge." Crowning one of the summits is a great catch basin with large cisterns under them which still hold enough water, apparently, for several regiments.

We strolled over most of this territory with Governor Best, who gave us much information regarding the ruins which surrounded us.

At the end of the ridge, facing the windward coast, is a lonely cemetery in which stands a monument to His Majesty's

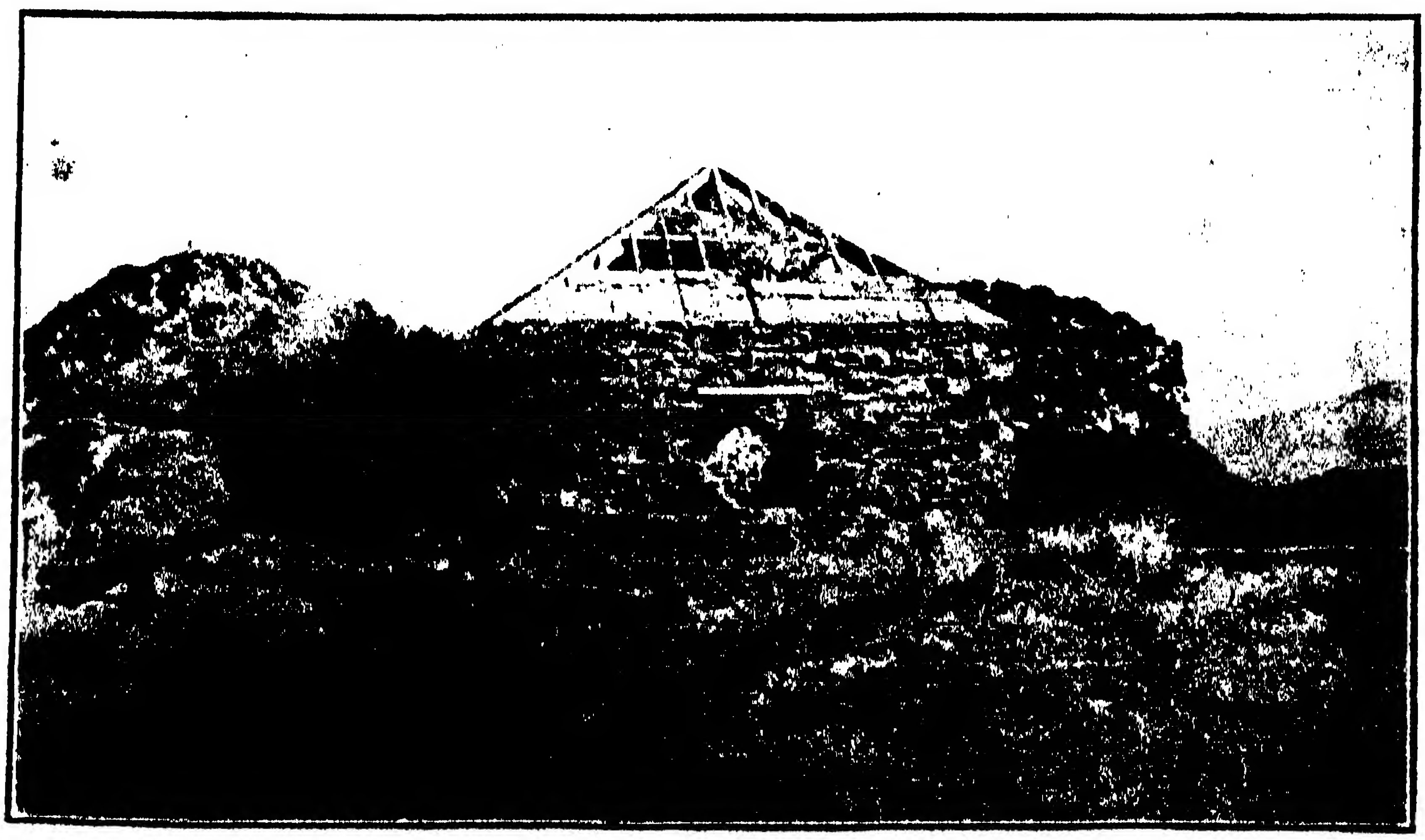


FIG. 18. THE POWDER MAGAZINE, FORT BARCLAY.

FIG. 10. RUINS OF THE OFFICER'S QUARTERS ON "THE RIDGE."

men of the Leeward Islands who sleep their long sleep undisturbed by human presence or activity, with the ever restless surges of that stormy coast for requiem. Most of these men had been victims of yellow fever which had decimated their ranks in the decade between 1850 and 1860. Some wanton has plastered over the inscriptions on three sides of this monument with hard cement, thus obliterating most of the record.

Many individual graves are there, with stones toppling over and the inscriptions fast becoming obliterated. The 4th Royal Artillery lost many of its members here, and that organization has recently put the place in as good repair as possible, clearing the ground from the invasion of the jungle and straightening many of the grave stones. The thought uppermost in the mind of the writer in such places is the utter futility of it all! We

strut upon the stage of life for such a pitifully short moment of time, and then our friends attempt to save us from oblivion by erecting monuments which soon topple over and the graven record of our short existence is wiped off by the hand of time, and strangers come and wonder who it was that rests in the eternal solitude of the place!

Below the point on which the cemetery rests is a great cliff of sandstone, carved by the pounding breakers into a series of gigantic pillars, known as the "Pillars of Hercules." This is one of the most picturesque of all the scenes about English Harbor, and we often dodged the breakers while collecting on the rocky flats below this ocean-sculptured cliff.

Standing near the monument and looking northward we find the whole panorama of the English Harbor region spread out as on a map. Far below is the dockyard and still beyond is Ordnance Bay with its fringe of mangrove swamp; while to the north of the dockyard rises Monk's Hill, formerly very extensively fortified, on the top of which perches the signal station from which the passage of all vessels is reported.

Returning to the dockyard towards sunset, we are in time to see the multitudes of bats streaming from the attic of Capstan House on their nightly foray against mosquitoes and other night-flying things. We believed that our immunity from malaria was largely due to the activity of these swarms of bats which reduced the numbers of the malarial mosquito to insignificant proportions.

FIG. 20. A CATCH-BASIN WITH LARGE CISTERNS UNDERNEATH.

FIG. 21. HIS EXCELLENCY, ACTING GOVERNOR T. A. V. BEST OF ANTIGUA.

After supper we sit on the veranda and dream of the past glories of the place, and particularly of the Great Admiral and his colleagues, the Olympian heroes of the Mistress of the Seas. We Yankees seem something of a misfit here. Nelson and his associates were, to say the least, not cordial in their attitude towards the United States shortly after the Revolutionary war; and the feeling was reciprocated with enthusiasm. He "drew down on himself no little odium by the efforts he made to prevent smuggling between the new United States and the British Colonies," according to the Encyclopedia Britannica.

If Nelson and his fellows do actually revisit the place in spirit, they must have been distinctly unhappy on July 4, 1918, when a party of American naturalists celebrated our national holiday at the old dockyard.

Early in the morning of that day Governor Best called us up by telephone to express his cordial good wishes, saying that he remembered what the day means to us and hoping that it would be a happy one. Nothing could have more forcibly impressed us with the cordial relationship now happily existing between the great English-speaking nations.

At our suggestion the historic flag of Clarence House was brought over and spread to the breeze beside the stars and stripes in front of the officers' quarters. After breakfast an imposing personage of colored extraction asked for an interview, and, bowing low, delivered himself as follows: "We understand, perfessor, that this day is your Xmas; and I desire,

with your permission, to bring my string band and give you pleasure." I explained that the day was a national and not a religious holiday with us, and accepted the proffered entertainment with thanks.

Soon the music was heard in the direction of the dockyard gate; and the band, led by Potter, marched around to the front of the quarters, countermarched, and took its place beneath the veranda on which we were assembled. The band consisted of six pieces in the hands of men and boys down to the age of a little fellow of eight or ten. There were a fiddle, two guitars, a mandolin, a triangle and a "pipe." This last was literally a two-inch gas pipe, bent at one end like an umbrella handle, into which a boy blew with distended cheeks and produced a series of deep grunts all in the same pitch and keeping excellent time. It seemed to function as a bass drum in the aggregation.

At the sound of this inspiring music the servants gathered from all quarters and a dance was soon in full swing. Even the ponderous cook was grasped around a fraction of her generous waist by Potter himself, and the shuffle of bare feet kept time with the booming of the pipe. They danced with much swaying of the body and little movement of the feet, their faces illuminated with an ecstasy of exalted emotion. Such, I imagine, was the face of David, as he "danced before the Lord"!

This music kept up for several hours. In the afternoon we had speeches appropriate to the occasion. By all odds the best

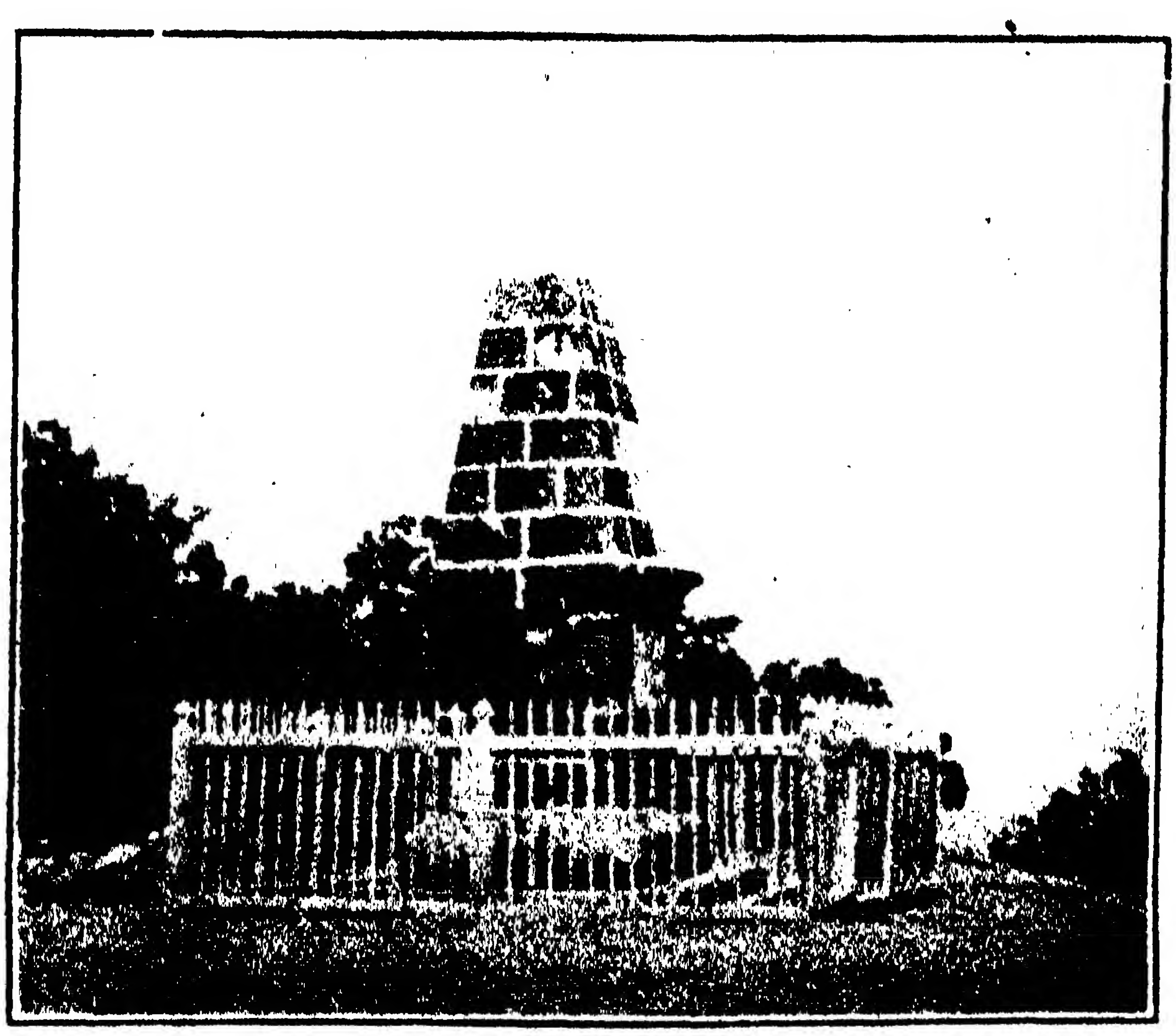


FIG. 22. THE SOLDIERS' MONUMENT ON THE RIDGE.

FIG. 23. "PILLARS OF HERCULES," ENTRANCE TO ENGLISH HARBOR.

FIG. 24. THE FOURTH OF JULY DANCE AT THE DOCKYARD.

of these was an impromptu one by the Rev. Hal Shepherd of St. Paul Parish, who gave a snappy address, full of patriotism and good will.

By a curious coincidence we were staying at Government House at St. Johns on July 20, when the Governor received and read to us a cablegram announcing the success of the American troops in the initial drive which developed into the victorious offensive that ended the Great War. That evening, after dinner, we joined most cordially in toasts proposed by His Excellency to "The King," and "The President of the United States."

And the memory of those two flags, side by side in that old British stronghold, as they were in the battle line in France, will remain with us longest of all the mental pictures of our visit to English Harbor.

THE PROGRESS OF SCIENCE

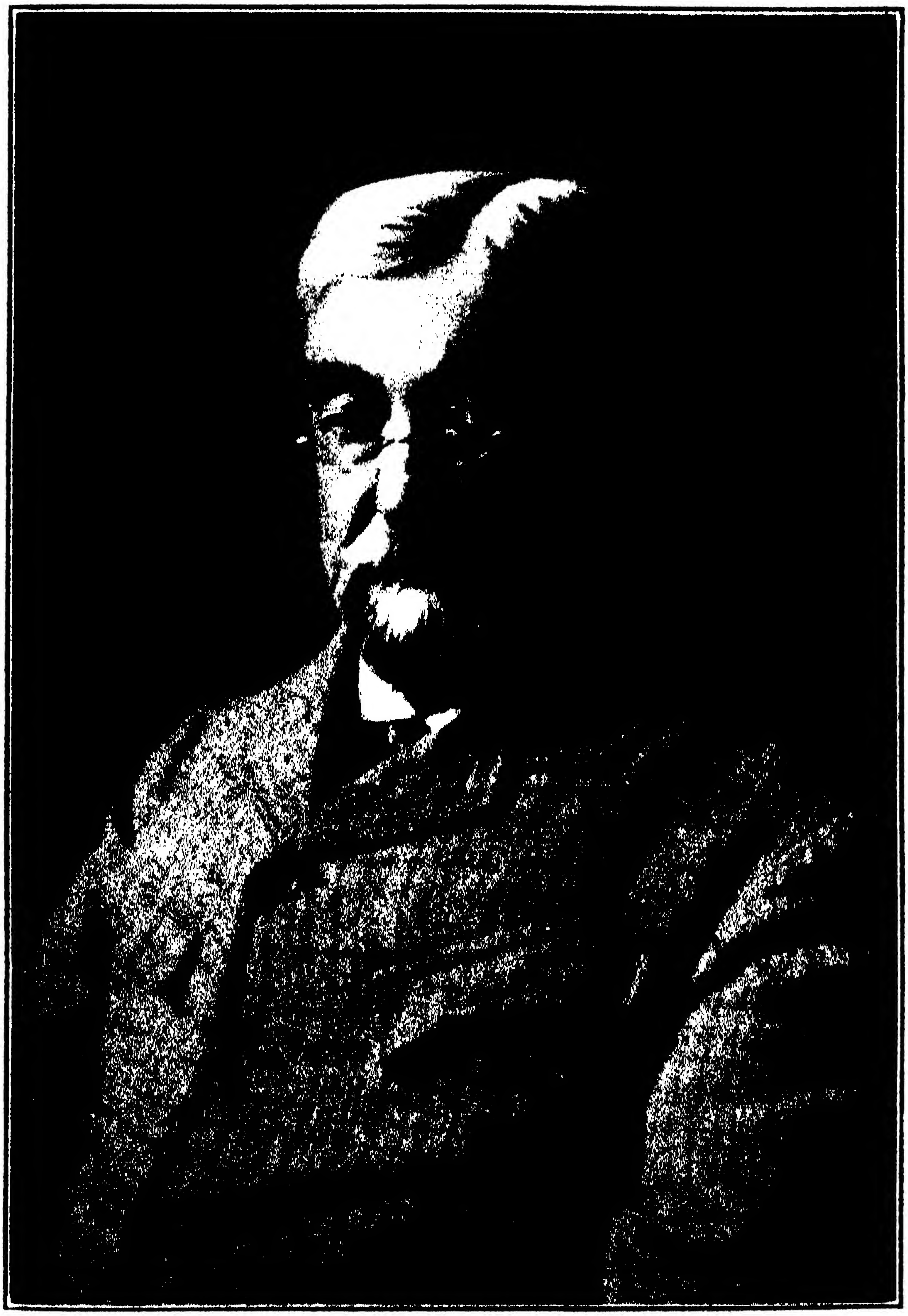
THE DISTRIBUTION OF MR. ROCKEFELLER'S GIFT FOR EDUCATION

It will be remembered that on last Christmas Day there were announced gifts by Mr. John D. Rockefeller of $50,000,000 to the General Education Board and $50,000,000 to the Rockefeller Foundation, the money to be available for immediate use. The former gift was primarily for the increase in salaries in colleges and universities, Mr. Rockefeller saying: "While this gift is made for the general corporate purposes of the board, I should cordially endorse a decision to use the principal, as well as the income, as promptly and largely as may seem wise for the purpose of cooperating with the higher institutions of learning in raising sums specifically devoted to the increase of teachers' salaries." In transmitting the gift to the Rockefeller Foundation Mr. Rockefeller specifically authorizes the trustees to utilize both principal and income for any of the corporate purposes of the foundation which, as stated in the charter, are "to promote the well-being of mankind throughout the world." While imposing no restriction upon the discretion of the trustees Mr. Rockefeller in his letter of transmittal expresses special interest "in the work being done throughout the world in combating disease through improvement of medical education, public health administration and scientific research."

While there are serious dangers in perpetual foundations that may control education and research, Mr. Rockefeller deserves sincere appreciation for the manner of his gifts and the objects to which they are devoted. In making the principal as well as the interest available for immediate use, thus meeting the emergency until the people learn the need of adequate support of education and research, an admirable example is set. In combating disease throughout the world by the promotion of medical education, public health administration and scientific research, the foundation follows the most important and the most promising direction of public service.

There are now announced large appropriations from these gifts. The general Education Board has appropriated for endowment to increase salaries the sum of $12,851,666 to about a hundred institutions on condition that they shall themselves reach the goal they had set and secure for the same purpose supplementary sums aggregating $30,613,334. Thus, these colleges and universities if successful will increase their endowments available for teachers's salaries to the extent of $43,465,000. An additional sum of $2,184,384 was appropriated covering a period of one to three years for immediate use in increasing salaries.

For medical education and research $5,000,000 has been alloted to endow a medical school at the University of Rochester, Mr. George Eastman giving $4,000,000, in addition to the $1,500,000 he had already given for a dental dispensary. The Foundation further gives $1,320,000 to the Washington University Medical School; $1,000,000 to the Yale Medical School; $750,000 to the



SIR NORMAN LOCKYER,

The fiftieth anniversary of whose editorship of *Nature*, the English weekly journal of science, has recently been celebrated. Sir Norman Lockyer, who is now eighty-four years of age, has been director of the Solar Physical Observatory, London, and a leader in astronomical research.

THE EDISON MEDAL AWARDED TO WILLIAM LEROY EMMET BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS FOR INVENTIONS AND DEVELOPMENTS OF ELECTRICAL APPARATUS AND PRIME MOVERS.

Harvard Medical School and $400,000 to the Johns Hopkins Medical School.

Since the Rockefeller Foundation is cooperating with governments in many parts of the British Empire, it recognizes the importance of aiding medical education in London, where the training of personnel and the setting of standards for health work throughout the empire are so largely centered. It has consequently offered to give about $6,000,000 to the University of London for the medical school and hospital of University College. Dalhousie University Medical School receives $500,000, and the Medical Research Foundation of Elizabeth, Queen of the Belgians, at Brussels, $200,000.

THE FOURTH ANNUAL MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE fourth annual meeting of the Pacific Division was held at Seattle in quarters provided by the University of Washington on June 17–19, 1920. The 1919 meeting held at Pasadena was a pronounced success, exceeding in point of interest and attendance any previous meeting, and fully justifying the wisdom of the national council in providing for a geographic division of the American Association to accommodate the large and active membership residing west of the Rocky Mountains.

Notwithstanding the long distance between centers of population on the Pacific coast, or perhaps rather on account of them, the executive committee has pursued the plan of holding the annual meetings alternately in different and widely separated sections of the Pacific Coast area, believing that although the largest attendance is not to be realized in this way, it best serves the purposes of the organization in stimulating an active interest in science throughout the district and in promoting that cooperation among scientific men which must be effective in meeting local problems.

The Exploration of the North Pacific Ocean was discussed at the Pasadena meeting in a symposium which outlined in a general way the urgent need of launching this project and the great practical benefits which must accrue. Some of the many scientific problems involved in the undertaking were also presented by prominent specialists who took part in the symposium. Credit should be given to Dr. William E. Ritter, of the Scripps Institution for Biological Research, who fathered this symposium and whose vision of the great economic and scientific advantages to be gained by international cooperation in this enterprise now seems in process of realization. At least the attention of the National Research Council is directed to the matter and a committee has been appointed which will report on ways and means. This committee has already held one meeting and will meet again in Honolulu in August of this year. This enterprise is felt to be of peculiar significance to the Pacific coast, and a second symposium on "The Animal and Plant Resources of the North Pacific Ocean" was presented at the Seattle meeting. The fisheries, as constituting the most considerable present resource of the ocean, received major consideration in this symposium, and Seattle as the center of the fishery industry, was the logical place in which to develop this phase of the subject.

Thursday evening, June 17, was devoted to the address of the retiring president, Dr. John C. Merriam, on "The research spirit in everyday affairs of the average man."

THE PAN-PACIFIC SCIENTIFIC CONGRESS

As the result of informal conferences and much correspondence, a scientific congress has been organized to meet at Honolulu, August 2 to 20, 1920, under the Chairmanship of Professor Herbert E. Gregory of Yale University, now on leave of absence for scientific work in Hawaii.

The purpose of the congress is to outline scientific problems of the Pacific Ocean region and to suggest methods for their solution; to make a critical inventory of existing knowledge, and to devise plans for future studies. It is anticipated that this congress will formulate for publication a program of research which will serve as a guide for cooperative work for individuals, institutions and governmental agencies.

Representative scientific men from the countries whose interests in whole or in part center in the Pacific will be present, and a number of men whose researches demand a knowledge of the natural history of the Pacific islands and shore lands have expressed their intention to attend.

The program of the conference is in the hands of the Committee on Pacific Exploration of the National Research Council, which consists of the following members: John C. Merriam, University of California, chairman; Wm. Bowie, U. S. Coast and Geodetic Survey; R. A. Daly, Harvard University; William M. Davis, Harvard University; Barton W. Evermann, California Academy of Science; Herbert E. Gregory, Yale University; E. B. Mathews, National Research Council; George F. McEwen, Scripps Institute; Alfred G. Mayor, Carnegie Institution; William E. Ritter, Scripps Institute.

The meetings will be arranged to place emphasis on the following topics: Research desirable to inaugurate; projects described in considerable detail with reference to their significance, and their bearing on other fields of study. Investigations designed to lay the foundation for a higher utilization of the economic resources of the Pacific may be included. Methods of cooperation with a view to eliminating unnecessary duplication of money and energy. The best use of the funds now available and the source of further endowments.

In addition to those maintained by the Federal and Territorial governments, the active scientific organizations of Hawaii include the Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History, the College of Hawaii, the Sugar Planters' Experiment Station, The Marine Aquarium and the Volcano Observatory. Between Honolulu and San Francisco regular sailings are maintained by four steamship companies, and established routes bring Hawaii into connection with Canada, New Zealand, Australia, the Philippines, China and Japan. In order to procure desirable accommodations, reservations for both outward and return passage should be made at an early date.

SCIENTIFIC ITEMS

We record with regret the death of Dr. John Nelson Stockwell, of Cleveland, known for his contributions to mathematical astronomy; of Marvin Hendrix Stacy, professor of civil engineering and dean at the University of North Carolina; of Dr. Alexander Ferguson, professor of pathology in the School of Medicine, Cairo, and of Frederick Kolpin Ravn, professor of plant pathology in the Royal Agricultural College of Denmark.

THE SCIENTIFIC MONTHLY

AUGUST, 1920

THE PHILOSOPHY OF HERBERT SPENCER[1]

By Professor A. H. LLOYD

UNIVERSITY OF MICHIGAN

"AS I take my pen in hand"—to begin with a quotation neither learned nor, so far as I know, from Spencer—I recall a course of lectures, heard in graduate school days well over a quarter of a century ago and given by Josiah Royce, on the philosophy of nature. The first half of the year Royce devoted to Benedict Spinoza, of the seventeenth century (1632–1677), advocate of an essentially mechanicalistic or, as Royce put it, "world-formula" view of the universe; and the second half, to Herbert Spencer, of the nineteenth century (1820–1903), advocate of a biologic or, since there is a difference, biologistic theory of the universe. The lectures on Spinoza were among the most helpful lectures I ever heard. Royce's understanding of the great Jewish philosopher was keen and sympathetic without being uncritical. Spencer, I felt then and feel now more definitely, he failed to appreciate either pro or con. I remember hearing him say that Spencer was a very important man, being a thinker whom all thinkers, scientists and philosophers, found it necessary, however easy, to refute. The scientists, it seems, found him too philosophical; the philosophers, too scientific; so that his success may be said to have fallen between the two. Thus he was actually and successfully neither, because on the whole both. Just such in-between-ness, moreover, if I may manufacture such a word, is a general character of Spencer's work, to be seen in other ways besides this of its falling in between science and philosophy. But, as

[1] One of three papers read at the annual "Memorial Meeting," celebrating the centenary of John Tyndall, 1820–1905, and Herbert Spencer, 1820–1903, of the Research Club, University of Michigan. The other papers were "John Tyndall," by Professor A. W. Smith, and "Herbert Spencer," by Professor Charles H. Cooley, the former published in this Journal, the latter to be published in the American Journal of Sociology.

to Royce's view of Spencer's importance, it amounted, as I recall, to little more than this. By common consent Spencer can not be or at least twenty-five years ago could not be overlooked; for right views of the great things of life, including the universe, the ground must first be cleared of Herbert Spencer. Here doubtless was real tribute, but hardly flattering; it lacked, to say the least, direct enthusiasm.

Royce's view, furthermore, while by no means without some foundation, was nevertheless in effect distinctly unfair, being at least only half of the truth. Royce himself, I am sure, would not wish to be taken too seriously. Of course his bias was always more for the great continental idealists, Kant, Hegel, Fichte, than for the English empiricists, Bacon, Locke, Mill, Spencer. Still, this bias aside, Spencer's importance is not really to be measured so much by his formal doctrines and their technical contributions to either science or philosophy, although these have had some value, as by the large enterprise which they both manifest on Spencer's part and have invited among others, the unusually general attention which, as embodied in the Synthetic Philosophy, they attracted in England and especially in America, as well as on the continent, the new directions to which they effectively turned scientific interest, and their generally transitional significance. To say just a word in passing about Spencer on the continent, I can not forget that after my Harvard studies in philosophy, during the years of which I was constantly sent to the works of the great continentals, I went to Berlin and Heidelberg only to find that the continentals were frequently referring their students to Locke, Spencer and others across the Channel with great respect.

Now, in general, "in-between-ness," referred to here as a typical character of Spencer's work, will no doubt appear more or less ignominious; but sometimes it is really significant and productive. Thus, as to Spencer's success falling between science and philosophy, while scientists never accepted or, if accepting, soon outgrew his science, finding it too philosophical, they were for a long time very generally disposed to accept much of his philosophy, his agnosticism, his evolutional perfectionism, his general mechanicalism. Especially was his agnosticism peculiarly grateful to them. "If religion and science are to be reconciled," he declared, "the basis of reconciliation must be this deepest, widest and most certain of all facts—that the Power which the Universe manifests to us is utterly inscrutable," that it is "not a relative but an absolute mystery." Again, with flattering respect for the knowledge

of the scientist: "He [the scientist], more than any other, truly *knows* that in its ultimate essence nothing can be known." Also: "Ultimate scientific ideas . . . are all representative of realities that can not be apprehended." If the scientists so welcomed Spencer's philosophical isms, the philosophers on their side, while objecting to his notion of philosophy as only the general science, science of the sciences, welcomed his special scientific compilations and formulations, buying his large volumes, contributions to biology, psychology, sociology, as well as his *First Principles*, generously. So was Spencer, scientist and philosopher, in each one of his two capacities a prophet not without honor save in his own country and this, especially in his time, was important. Such mediation has at times great value. Spencer ranks, in other words, among those who have made the two countries, science and philosophy, realize that they must reckon with each other; each admitting the other to its counsels. How fitting, I venture therefore to reflect, that this club, catholic in its organization, should celebrate the centenary of the great Synthetic Philosopher.

A second evidence of Spencer's in-between-ness has to do, not now with any general relation between science and philosophy, but with the fact of Spencer's thinking coming at a time of transition in the history of science, when one scientific point of view as the commanding and leading view, directly and vitally interesting, was becoming only secondary and mediate, yielding the leadership to another and quite different view, and so when philosophy was also on a new venture. To explain my meaning here I must seem to digress a little and also I may be telling most of you here only an old story.

Philosophy has ever been a handmaid, albeit rather independent and not always even respectful in her service, being quite critical and correctional at times, of positive doctrine in one form or another. When in such service, moreover, philosophy's irrepressible and to her mistress often very discomfiting instinct has been for universal applications, for widest possible—and impossible!—generalization, for liberation of the spirit from the always too special and confining letter; and her service itself, accordingly, has been, however obstinate the mistress, what our genial professor of music with his lectures on "Creative Listening" would be sure to style a creative service. Thus, first, in the history of Christendom philosophy was handmaid of the Church, *ancilla ecclesiæ*, and of the Church's peculiar positive doctrine, its orthodox and dogmatic theology, which asserted, *as should be remarked with special care for the sake of the contrast to be pointed out hereafter*, a single

first cause and put human life under constraint of a single institutional uniformity, essentially mechanicalistic and local in character. Then, leaving her first position, in the seventeenth and eighteenth centuries she took service under mathematics and natural mechanics, for which—*now mark the contrast*—causation and uniformity were no longer single and institutional or locally mechanical, but general, that is, extended to include all nature. So came into the logic of science the now well-known principles of *universal* causation and of the uniformity of ALL *nature.* Science has never been without her debt to theology!

But, thirdly, in this story of Christendom's great adventure in civilization or, more narrowly, of philosophy's creative service of science, and now with special interest for our study of Spencer, biology—under its conception of organism in distinction from mechanism, an organism being supermechanical or being mechanism become general and naturally, innately versatile, versatile even to the point of genius, and of evolution in distinction from only once-upon-a-time creation—biology, I say, became the mistress of the handmaid of all positive doctrine, philosophy. And a fickle servant indeed seems that handmaid, so often through the centuries changing her place. But, say what you will of her or of other handmaids, our story does show an effective and creative service. Theology, mechanics, biology; institutional conformity, natural conformity, natural versatility,—these do make a wonderful succession at once of positive interests and of bases of productive generalization. Well might we stop and dwell at length upon them and their progression. But stop we may not. It now concerns us only that to the period of philosophy's third service or perhaps more exactly to the later stages of the transition from the second to the third, Spencer and his Synthetic Philosophy, at once mechanicalistic in form and biologistic in meaning, seem to belong.[2]

[2] In an article, already published in this journal, May, 1920, "Philosophy in the Service of Science," I have tried to tell the story, given so briefly here, in more detail and, so to speak, with an additional chapter. Thus I have, among other things, pointed out that at the present time philosophy seems even once more to have changed her place, the new science, psychology, become *a natural science,* being now the mistress instead of biology and the conscious individual succeeding the biologist's organism in the sequence of ruling conceptions. The whole sequence, then, from theology to psychology, besides being interesting for Spencer's place and part in it, is interesting also as a record of man's original aloofness from nature gradually turned into the closest intimacy. Certainly psychology as a natural science quite outdoes biology and organic evolution in its intimations of the unity of man and nature.

Of course the biologism of the later nineteenth century had its preparatory antecedents. On the continent Leibnitz, Kant and Hegel, not to mention others, had transformed and so prepared logic and metaphysics for the new intellectual order. In England Hume and the Utilitarians, including notably John Stuart Mill, had been serviceable in their way, while nearly or quite contemporary with Spencer (1820–1905) we have Darwin (1809–1882) and Huxley (1825–1895) and—in France—Auguste Comte (1798–1857). Possibly the Scotch geologist, Sir Charles Lyell (1797–1875) should be named also, although in his work Spencer appears to have found more to reject and even resent than to accept. There was also the great physicist, Tyndall, 1820–1893. But, to speak at large, the biological theories of the time in their logic or their metaphysics or their science, implied or explicit, were obviously mechanicalistic, as in Spencer's case; although, significantly, with the mechanicalistic biologism, there was always in evidence, yet hardly in the leading rôle, a contemporary vitalism or occultism. Lyell was an early exponent of this and certainly biology, substituting the super-mechanical organism for mechanism, could hardly avoid some vitalism hidden or indirect when not direct and open. This might seem reactionary; but also progress demanded it and, when the mechanicalists themselves denied and opposed, others were bound to rise up and protest. The very mechanicalists, moreover, had to admit some vitalistic principle into their houses, opening a back door for it, however tightly closed they might be keeping their front doors. Spencer himself, as I shall show, was not without his own indirect vitalism or occultism.

Spencer's mechanicalistic doctrines, first to take our attention, not only show his heritage from the past, but also, in addition to what has already been pointed out here, afford a very interesting example of an important principle in the development of science or of thought generally. A hint of this was given in an earlier paragraph when reference was made to one intellectual interest, becoming only mediate and yielding leadership to another. That sequence of interests or disciplines—dogmatic theology, mechanics, biology—is certainly more than just a sequence. Always in the sequence an earlier standpoint has become the medium or the method of what follows. The accepted reality of one time becomes only the way of looking, the formal useful points of view, say the working hypothesis, for the investigations of the next. In philosophical terms, an earlier century's metaphysics is a later century's methodology or epistemology. Just so, then, a pro-

gressing science or philosophy accumulates its useful standpoints and methods, its intellectual milieu, its categories, its mediating ideas or questions; exactly as for a progressing real life the cherished institutes of one era turn into the secular instruments of the next. All of which, I suppose, amounts only to saying, but I hope in a stimulating way, that new wine must always be put in old bottles. But fortunately or unfortunately, especially in times of critical transitions, men are all too likely to lag or lapse, confusing meaning with method, end with means. Many a scientist has done this, as well as many a practical man. Many a scientist has taken his working standpoint too seriously, hoarding it as does any miser, conceiving it as representing reality; and, to come now to the point, of those who have done just this Spencer is undoubtedly one; a notable example of it, too, for being both scientist and philosopher. Spencer has had mechanicalism for his manner of thought, his method, his phenomenology, while an organic world, the world of the biologist and evolutionist, has been the real object of his interest; and yet at least not clearly has he distinguished between the two. In his numerous changes of statement, as the years passed, there may be discoverable a growing feeling for the difference and so a freer biologism; but, on the whole, I am of the opinion that he never really escaped from his confusion of a standpoint and method, which the past had given his times, with the new meaning which was the real object. A biologist may have machinery in his laboratory; also he may picture mechanisms in the world he observes; and, studying specific positive acts and processes, he may actually find perfect mechanisms; but he may not stop with a purely mechanicalistic theory of the universe. Happily even our present hero did not stop there. He had, as has been said, his own occultism.

Perhaps, instead of going on with my tale, I should now give some illustrations, taken from Spencer's specific doctrines, of his mechanicalistic "possession." Before adducing such illustrations, however, I would consider his occultism, his very real although hidden super-mechanicalism, that the illustrations, when introduced, may illustrate this also. In his occultism Spencer will be seen a third time to have fallen between. Neither scientist nor philosopher, neither mechanicalistic nor freely biologistic, he proves also to be in between the traditional occultism and a natural, consistent evolutionism. A certain surviving, albeit secularized and disguised spiritualism—notice the small initial letter—has a real hold on his rationalistic science-and-philosophy.

Like most if not all of the earlier modern evolutionists, Spencer undoubtedly labored under a sort of tradition, I would almost go so far as to say a superstition, of an external, quite separately real, independent and objective environment, an outer and quite different world; persisting notion from earlier centuries. Evolution and biologism generally were plainly bound to imply and, becoming clear as to their meaning, to assert the real and vital unity of man and nature, of organism and environment; but science came to the evolution-hypothesis with the habits of mind of the Middle Ages. Whatever the ultimate logical demands of the new theory, then, in a long-standing practise, man, as to his real worth and character, was one thing, a creature not of this earth; the natural world, quite another, external and alien; and by easy analogy, say anthropomorphically, any living creature, any organism, and its environment were simply accepted as constituting a similar dualism. From man down even to the incoherently quivering protoplasmic mass the living being was thought of as having in its life the old problem of adaptation to something not really of its kind. Exactly so in the centuries of the Church's domination man had to live at least for a time, with reference to alien surroundings, his real self being quite aloof. Even a century or two of rationalism, while largely dispelling from nature the ghosts—almost too substantial in the old days to be so called—and the occult and arbitrary powers of all sorts, had failed to dispell the general notion of nature being independent and external. This circumstance, I am sure, had much to do, in the first place, with evolution's early mechanicalism and, secondly, with evolution's indirect, when not open and direct, occultism. However perfect the machinery, institutional and official at first, then physical or natural, adaptations could not be secured without help from outside. Whether exercising an evil spirit or winning favor from a good one, man had to depend on very formal and mechanical rites, perhaps on strict exactness of some phrase or sentence, and then also on help from Heaven or, as our university bulletins would put it, "some equivalent."

That Spencer did hold positively to an external and alien environment, making his general view of evolution, as well as his specific doctrines, accord with this idea, has always seemed to me to be clearly indicated, among other ways, in his emphatic agnosticism already remarked here. Science, you will remember, as well as religion or theology, he insisted, was confronted, not with a merely relative, but with an absolute mystery. In ultimate character and reality nature, as well as God,

was absolutely beyond man's reach. It is true that in his autobiography Spencer complains that his Unknowable, as presented in his *First Principles of Philosophy*, was getting altogether too much attention, that many of his readers and critics were scarcely noticing anything else; while he himself regarded it as almost if not quite secondary in importance to his doctrines about the knowable. Why should so many of those readers imagine that the whole Synthetic Philosophy must stand or fall by the Unknowable? Yet herein, to my mind, Spencer was more puzzled than candid. Certainly he shows himself, to say the least, quite lacking in appreciation of his own philosophy and its agnosticism. His Unknowable was in reality a critical point—perhaps even his heel of Achilles. It summarily alienated the natural world and so did perpetuate the medieval tradition—whether for reactionary effects or for progress need not now be said—within the very camp of rationalistic science and philosophy. Towards the end of his life Spencer confesses that orthodox ideas had been positively repulsive to him, more so than had been either necessary or wise, and it may be that his earlier and over-impulsive reaction to orthodoxy only played a trick on him, rendering him unreflective, more opposed than critical, and so caught by his enemy unawares, as very often happens with negatives. In any case, in Spencer's philosophy man, with all other living creatures, is left still with the problem of salvation in an alien world and solution of this problem necessarily had to conform to type.

That Spencer himself preferred the word adjustment, adaptation or accommodation to the, to him, repulsive word salvation does not affect the issue at all. Like salvation, adaptation had to rely on blind, incoherent, undifferentiated mechanical reactions supplemented by help from outside. Spencer, again, did not call the source of this help God or Providence or anything so conventional and widely respectable; but he was not less a worshiper at the altar of the occult. What saved his creatures was Happy Chance! Bless-ed be its name! Rationalism had indeed dispelled the old occult powers; no longer were these the almost universally accredited agents of man's salvation—or of his destruction; but the spirit of medievalism still walked so long as Chance held the rôle of Providence. Truly I can read Spencer without having my hair stand on end—how violent metaphors do sometimes become!—for the ghostly notions I constantly meet in his books; but mine is after all a phlegmatic nature and, say what you will, although one's hair may lie quite flat, Spencer's philosophy, its mechanicalism, its supermechanicalism, its biologism and all, is only a sort of rationalistic distillation and objectification of the orthodox

scheme of salvation. If to say this is to seem to ridicule Spencer, I must insist that my purpose is not ridicule. Laugh good-naturedly we may; but our laughter is not necessarily derogatory. New theory has to depend, as was said, on old habits of thought for its mediation and humor is inevitable. Moreover, in the present instance, the salvation itself gets new meaning when it is found repeated in the adaptive activity requiring at once mechanism and favoring chance, of every living organism!

Spencer's biographers, including himself, make very clear the rationalistic influences of his up-bringing. So far as we know, he never even had formally to reject the old theology, because the problems it stirred up seem never to have arisen as serious problems for him. Constantly he was meeting men of liberal and independent views, of the scientific spirit, objective in their outlook. Early he showed antipathy towards classical studies and humanistic education generally. Miracles, more discussed in his day than in ours, puzzling so many, seemed not to puzzle him, for miracles there simply were not; and mere sentiment counted for nothing, for of course it is always conservative. Spencer's father, it is true, was a Methodist turned Quaker, his mother a Methodist without any turning whatever; but apparently just this difference in his home made him, as if in self-defense, *neuter in re.* All these influences, then, of Spencer's life contributed to making him rationalistic, intellectually cold and objective, and yet, as has been shown already and will develop further, his philosophy also bears the sure marks of his outgrown home as well as of conservative England at large, suggesting withal the persistent scent of Thomas Moore's still fragrant roses. Great changes may come to science and philosophy, theology yielding to biology; but, as with broken and shattered vases, the past is hard if not impossible to lose. A man may look with all candor at what lies quite without; he may court the wholly objective view; he may cast aside all that is institutional in letter or in spirit; but, to use as a figure what has its literal meaning too, he can not escape the fact that his parents gave him his eyes. Generalization, with its ever wider and deeper view and different valuations, may bring changes; but the new view or the new life must always conserve the past. Contempt for the old, accordingly, and blindness to the new are both lacking in realism, if not also in candor. In Spencer's case we have seen how his contempt may have been the cause of his blindness.

I turn, finally, to some illustrations among Spencer's doctrines. Perhaps I should consider first his comprehensive formula for evolution:

An integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite incoherent homogeneity to a definite coherent heterogeneity; and during which the retained motion undergoes parallel transformations.

But, assuming that I could satisfactorily and intelligibly discuss that remarkable formula, focus of the Synthetic Philosophy, I fear I could not do so in the time at my disposal. Instead, therefore, I have chosen for your attention three lesser but wholly characteristic doctrines, making my selection somewhat at random. Thus, first, I shall consider the doctrine of adaptation or adjustment already in fact partially indicated; secondly, the doctrine of personal individualism; and, thirdly, that of the finally perfectly adjusted man; these doctrines coming from the Principles of Biology, the Principles of Sociology and the Principles of Ethics, respectively.

Spencer's doctrine of adaptation is a doctrine, shared by him with a contemporary Scottish philosopher of some note, Alexander Bain, and accordingly sometimes known as the Spencer-Bain theory, which pictures an organism, confronted by a strange environment, in a condition of action through random impulses, incoherent, undifferentiated nervous discharges, manifold indefinite mechanical reactions, and assumes that chance will bring a successful adaptation from one of these impulses, discharges, reactions. The theory thus takes very seriously the very familiar method of trial and error, except that the trials are wholly random and success has to depend quite on fortune. The more numerous the trials, obviously, the merrier the probability of a success and, I suppose, at infinity a success would be assured. An adaptation happily secured, this is, so to speak, registered and stored and becomes henceforth a line of least resistance for future action, say a definite activity in repertory. Of course, if any real change occur in the environment, the process must be renewed from the beginning; while with manifold renewals an accumulation of acts in repertory is effected and the organism acquires a complex and versatile life answering to its varied environment. The whole process, moreover, revealing the progress or development of the creature concerned, may be described, in terms already heard, as a passing "from an indefinite incoherent homogeneity to a definite coherent heterogeneity," so that, after all, we are getting some understanding of Spencer's general formula for evolution. Parenthetically, if at times Spencer seems to us a bit commonplace and prosaic and even superficial, we must remember that his work belongs to the third quarter of the last century. Indeed his First Principles appeared in first edition over fifty years ago.

Spencer's doctrine, quite consistent within its premises, is to be criticized just for its premises. Before a wholly strange environment, which is assumed, any organism must be, or at once be rendered, quite incoherent, broken, without unity, not even vitally or really an organism, and so must depend on chance for success and on mere multiplication of chance successes for growth. But, as we know, consistent evolution can not suppose a strange, external environment. Accordingly the theory has at its start a false foundation. Indeed it is also more than questionable if the theory has any natural right to its claim of coherence being attained eventually; for not merely would adjustment, or evolution in general, depend on the occult in the form of happy chance, but also it would depend on the occult in the form of an agency of coherence. Coherence is certainly quite impossible against an alien environment and it can never be acquired by a mere manifold of successes. "Favor my random ventures," we who have ears hear Spencer's organism praying fervently to the Unknowable, to that absolutely mysterious Power behind all things; "Favor my ventures and, above all, give me, unworthy and hopelessly broken creature that I am, a real and an abiding coherence;" and, while sympathetically we who have hearts may hope that so earnest a prayer will be answered abundantly, we have once more to be entertained. That a creature of Spencer's should be thus brought to kneeling and piety!

The life of an organism Spencer defines as "the power of continuous adjustment of internal relations to external relations." Here, then, is further light on his doctrine of adjustment. Professor John Watson finds the definition true enough physically or mechanically, but inadequate biologically.[3] A stone's power of adjustment, as it settles, for example, in the yielding earth or as it meets the blow of the shattering hammer, might be so described; but "a living being [with its own internal relations] is a unity in a different sense from that in which we speak of a stone." A living being, an organism, must be originally and persistently endowed with an inviolable unity and self-identity and therefore must not for a moment be thought of as ever adjusting itself to an environment so external or in such a way external as to violate that unity or identity and in consequence to require a miraculous restoration. So is Watson's criticism quite in line with that suggested here. Moreover, Watson's emphasis on the differences between unity or coherence of a stone and that of an organism and again between the processes of adjustment of the two unities to their

[3] "Comte, Mill and Spencer." By John Watson, LL.D. Pp. 103 sq. The Macmillan Company. 1895.

respective external surroundings has suggested to me that, meeting in Spencer's philosophy, are to be found, not only two ideas of unity, the mechanical and the biological, and two corresponding ideas of adjustment, but also two ideas of the external. In any case, had Spencer and others of his time really appreciated that biologism and its evolution-hypothesis were bringing to human consciousness and feeling, to be of value both in common human practise and in general scientific theory, a qualitatively different external world, external I mean under a distinctly new valuation, in a distinctly new sense, from that of earlier centuries, I am sure they would not have taken the theory of random discharges, chance successes, and only eventual and virtually magically given coherence quite so literally. Historically unity, adjustment, externality are by no means univocal terms and it is simple-minded and prosaic to suppose them so. Theology, mechanics and biology have given each one three different meanings. A little more poetry in Spencer's worthy soul had served him well! And yet, when all is said, it may be added, as the final word, that in thinking as in life to hasten progress is often to obstruct it.

Secondly, I would consider with you Spencer's personal individualism. This appears in various ways and places; in his writings on education, urging primary regard for the individual; in his hedonistic ethics; in his political papers, assertively democratic; and, especially, in his Sociology. In the last under evident pressure from the tendency to biologism and from the biological idea of organism, but under pressure also from old habits of thinking, he raises the question of society being an organism and decides to concede organic character only under what some would style, with timely allusion, senatorial reservations. Certainly outwardly society remains, when Spencer has finished, no organism at all and individuality appears to have lost none of its traditional prerogatives. Yet, of course, there was progress in the mere putting of the question and possibly, had Spencer asked, not if society were an organism, but if it were organic, his conclusion had been different. The latter query had allowed some imagination. He held back, however, here as in other matters. He did find certain similarities of society to an organism: Both commonly, normally, increase in size, as they get older; in complexity, too, and in interdependence of parts; and both are wholes that live on in spite of, or even because of, the death of their parts. Still none of these things show any very deep notion of what constitutes real organic character and, if they did in any degree, the intended argument would be discredited so soon as the four points of dissimilarity, emphasized by Spencer, had been re-

marked. Thus, unlike an organism, society has no visible form and no continuity of mass and has distinctly autonomous parts and parts each with its own independent consciousness. How superficial this is both as to its dissimilarities and as to its similarities; how dependent the argument of it, pro and con, on inadequate tests. Why dwell on questions of mere mass and continuity that must be irrelevant? Why fall back on autonomy and independent consciousness, when these, as sure to be understood, can only obscure the real point? Why let the idea of organism, individual or social, suffer thus from traditional physical tests, on the one hand, and traditional notions of the individual as an unworldly, spiritual being, on the other, when the idea itself was really a call for important revisions of both? Spencer's argument, then, proves and disproves nothing. Nevertheless, there was, I repeat, progress in the mere putting of the question. Any important question or issue, once clearly put, is always stronger than the superficial ways in which it may be attacked and momentarily solved or than the conventional reservations with which its solution may be compromised or more seriously obstructed.

Possibly, to indulge my own imagination, Spencer was thinking of society as confronted, like an individual, with a strange and hostile environment and so rendered inorganic, incoherent, loosely pluralistic; but, whether this was the imagery in his mind or not, his conclusion of a pluralistic individualism is wholly consistent with it and with its various conservative implications. Even an individual organism, we should remember, was made incoherent, a loose plurality of acts, by its external surroundings and, neither originally nor eventually, could honestly claim any true organic character of its own. Why! On this showing Spencer might have said that society was at least as organic as any organism! His insistent individualism had really suffered no serious shock thereby. As to his intellectual conservatism, which we are constantly confronting, there is surely in it a suggestion of the reserve which the Englishman has seldom if ever failed to exhibit, holding to his past in his most progressive moves whether of thought or of life.

For the rest, in this account of Spencer's individualism and his hesitation to see anything really organic in society, I would say, even a third time, that his question alone was a step forward. Indeed this is true of his other characteristic queries. While so many of his various answers were soon discredited, the questions themselves were vital and the new direction which they undoubtedly gave to scientific interest was significant and productive. He may have resented the old humanities, senti-

ment, orthodoxy and other things in kind; but he turned science to human affairs in a very effective way. Is society organic? What really is this thing we have been calling life? How indeed do organisms accomplish their undoubtedly successful adaptations to environment? Or human creatures, individually or socially, to the natural world? Prophetic and creative interests, all of these; getting from Spencer only constrained and inadequate answers, but only more persistent as questions on this account.

Lastly, Spencer was an evolutional perfectionist. All in good time, but by gradual evolution, not by cataclysmic upheaval, the millennium would arrive! Spencer's doctrine of the finally perfectly adapted man, or of the finally perfectly adapted humanity, is to my mind at once the most significant and the most characteristic of all his doctrines. It shows him so clearly "in between" the old and the new. It shows him bringing spiritual man to earth, but also raising earth at last to an only Golden Heaven. Every day will be Sunday by and by! Not that Spencer said this in such words; but such was his vision. What he did say to that effect is worth quoting even at some length. In his "Data of Ethics," a late work appearing in 1882,[4] after apologizing and elaborately explaining himself for distinguishing between an absolute and a relative ethics and for the apparently resulting dualism, with one code for creatures not of this present earth, and another for present earthly and commonly human creatures, he proceeds as follows:

> The alleged necessary precedence of Absolute Ethics over Relative Ethics is thus, I think, further elucidated. One who has followed the general argument thus far, will not deny that an ideal social being may be conceived as so constituted that his spontaneous activities are congruous with the conditions imposed by the social environment formed by other such beings. In many places, and in various ways, I have argued that conformably with the laws of evolution in general, and conformably with the laws of organization in particular, there has been, and is, in progress, an adaptation of humanity to the social state, changing it in the direction of such an ideal congruity. And the corollary before drawn and here repeated, is that the ultimate man is one in whom this process has gone so far as to produce a correspondence between all the promptings of his nature and all the requirements of his life as carried on in society. If so, it is a necessary implication that there exists an ideal code of conduct formulating the behavior of the completely adapted man in the completely evolved society. Such a code is that here called Absolute Ethics as distinguished from Relative Ethics—a code the injunctions of which are to be considered as absolutely right in contrast with those that are relatively right or least wrong; and which, as a system of ideal conduct, is to serve as a standard for our guidance in solving, as well as we can, the problems of real conduct.

[4] The "First Principles" was published in 1862.

So wrote Spencer, scientist and philosopher; evolutionist, too; but under restraint, being also perfectionist and, except that he set no thousand year limit, millenniumist. All in good time, he assures us absolute right will have become as natural as it is right and, man having then come to a perfect correspondence between his natural promptings and the requirements or obligations of his surroundings, between his internal relations and their external relations, the true and absolute ethics, so impractical now, will be practical as well as true, and confidently and safely can be installed or promulgated; being of course for the imperfect present only ideal, abstract, otherworldly. Safely, I said, because, according to Spencer, who would bring his ideal to earth, the moral ideal is pleasure. Only perfect men can safely be pleasure-seekers; not so, *human* men. Herbert Spencer should have read William Paley, who at the close of the eighteenth century had successfully shown the hedonistic character of orthodox Christianity.[5]

Spencer's philosophy, I conclude, is an imprisoned biology or biologism. In form and spirit it is often conventional, traditional, commonplace, prosaic; its manner of expression, its literary style, shows the one-sided character of his education; but also, as a philosophy, it is productively quick with real, insistent and especially in his day very timely problems. He himself had great confidence, a Britisher's confidence, in his work; as is shown, if showing be necessary, by his remarkable persistence and accomplishment under circumstances of invalidism that would have discouraged others. It must be a real tribute to him, much more positive than that quoted from Royce, that we can see, as it were, looking out from behind the imprisoning bars, the new view of life and the world, which biologism, suceeding seventeenth and eighteenth century mechanicalism, has really effected.

[5] Spencer's millennial perfectionism, it is worth while observing, illuminates a certain point, not indeed touched upon here, of his sociological doctrine. Perfection accomplished, there will be, it is true, perfect accord between individuals and society; but up to the time of such accomplishment individuals, exactly as Spencer represents, must always be naturally more or less anti-social or at least assertively independent of the body politic, and society as served by the state must therefore be at all times more or less compulsive or tyrannical and in periods of war or crisis of any kind distinctly so.

THE HISTORIAN AND THE HISTORY OF SCIENCE[1]

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1. The History of Science and the Interpretation of History

THE history of science has been a subject of much discussion and a field for considerable productive activity, but most of such discussion and activity has been carried on by natural scientists. It is a subject, however, which ought to attract much interest from historians of liberal tendencies, and this article will attempt in a very brief way to estimate the significance of the history of science for historiography, to summarize the progress thus far made in the subject in this country, and to introduce a few generalizations concerning the desirable method of presenting it through the cooperation of historians and scientists.

The view of the significance of the history of science as a branch of historiography must necessarily vary with the attitude taken with respect to the nature of history.[2] If one adheres to the standpoint of Vico, Hegel, Kidd and the religionists, or to that of Thierry, Lamartine, Carlyle and the Romanticists, with their eulogy of heroic biography and their definite

[1] Revision of a paper read at the Conference on the History of Science at the American Historical Association Meeting, Cleveland, Ohio, December 31, 1919. The Conference was presided over by Professor George L. Burr, and papers were read by Professors T. Wingate Todd of Western Reserve University, Louis C. Karpinski of the University of Michigan, Lynn Thorndike of Western Reserve University, and Henry Crew of Northwestern University. It was the first general session of the American Historical Association ever devoted entirely to the history of science.

[2] The writer has attempted to summarize some of the various interpretations of history in his article on "History: Its Rise and Development," in the new edition of the *Encyclopedia Americana*. See also the article on "The Interpretation of History," by James T. Shotwell in the *American Historical Review*, July, 1913, pp. 692 ff.

[3] *Cf.* the presidential address of William Roscoe Thayer to the American Historical Association at Cleveland, December 29, 1919, on "Recent Fallacies in History," *American Historical Review*, January, 1920. See also his article on "Vagaries of Historians," in the *American Historical Review*, January, 1919, especially pp. 186 ff.

trend toward obscurantism, then there can, indeed, be little or no sympathy expected with the history of science. Nor can much more interest or approval be hoped for those who, with Seeley or Freeman, hold that history is the "biography of states" or "past politics," unless perhaps they might grudgingly admit that the invention of gunpowder or the steamboat has had significant results for the growth of national states and world empires, or that the scientific achievements lying back of the art of making modern artillery or steel armor for dreadnoughts may have slightly influenced the course of modern armed conflicts or greatly complicated the problems of national budgets. In fact, little sympathy or interest can be expected from the "eminent" and "respectable" historians as a group. No doubt President Thayer has already classified this conference as one of the most obvious "recent fallacies of historians."[3] The only type of historian who is likely to give serious and sympathetic attention to the history of science is the member of that renegade and outlaw, but ever increasing group which has transcended archaic and illogical conventions and dared to view history as a record of human achievement conceived in its broadest sense as the progressive establishment of human control over nature and the increasingly more perfect adaptation of nature to human use.[4] In this process science, pure and applied, has unquestionably been the dominating factor.[5]

This position can best be substantiated by adopting at the outset the more recent anthropological theories regarding the origins of science. Our concepts in this respect were for years perverted by the vicious generalization of Frazer to the effect that all of primitive science was to be found wholly in the realm of the occult, or, more specifically, in magical activities.[6] There has been no more significant revision of our anthropological background of cultural origins than that which has been forced through the critical work of Boas and his disciples, Marett and others, which has finally demonstrated the generic relation of religion and magic and has revealed the origins of science as proceeding primarily from the discoveries growing out of the everyday secular and commonplace activities of primitive peoples, however much such discoveries may later give a certain

[4] See the introductory paragraphs to the article on "History" by James T. Shotwell in the eleventh edition of the *Encyclopedia Americana*. See also James Harvey Robinson, "The New History," Chapter V.

[5] There is a brilliant passage on this point in Gabriel Tarde's "Les Transformations du Pouvoir," pp. 188–190.

[6] J. G. Frazer, "The Golden Bough," Vol. I., pp. 220–243.

religious sanctity to their makers.[7] To be sure, this view does not deny the all-pervading religious *milieu* of primitive life in all its phases, but assumes that magic, as a phase of primitive religion, has evident associations with primitive science and economic life. Nor do the more critical anthropologists claim to be able to clear up from a study of primitive peoples all the problems connected with the position of magic and science in the Middle Ages—a period which is a great historic complex of primitive survivals and advanced cultural states and products. The critical anthropologist admits freely that the medieval period is one preeminently for the historian to deal with, but insists that the historian should start right with an up-to-date and scientific anthropological outlook.[8]

When the origins of science are viewed in this more accurate manner the history of science has a peculiar significance for the general interpretation of historical development. The vital and probably causal dependence of political forms and processes upon economic factors and institutions has now been so well established as to make a reminder of the situation seem almost an antiquated platitude.[9] It has been less frequently and less clearly pointed out, however, that the progress of science has in turn given shape and direction to economic development from the very beginnings of cultural history. There have been those who have questioned this generalization and who have asserted that pure science has had no genetic connection with applied science and industrial inventions. They have based their position on the alleged derivation of science from primitive magic, which certainly did not direct and dominate, however much it may have been associated with, primitive industry, and on the assumption that the inventions which initiated the Industrial Revolution, the greatest economic transformation in human history, bore little sequential relation to previous advances in pure science. It has already been shown how inaccurate is the assumption of the identity between prim-

[7] An excellent critical review of the leading anthropological theories concerning religion and magic is given by Dr. A. A. Goldenweiser in an article on "Magic and Religion" in the *Psychological Bulletin*, March, 1919, pp. 82 ff.

[8] This subject has been surveyed by Dr. Lynn Thorndike in his "The Place of Magic in the Intellectual History of Europe." Professor Thorndike is now engaged upon an exhaustive treatment of the field of medieval science and magic.

[9] The literature on the subject is admirably analyzed by Professor E. R. A. Seligman in his "Economic Interpretation of History." The works of Professors F. J. Turner and C. A. Beard have been the most stimulating American application of the doctrine.

itive science and magic. The case of the Industrial Revolution, when critically examined, is not less damaging to the views of this group. Watt's perfection of the steam engine was based upon studies of atmospheric pressure by Torricelli and Von Guericke, Huyghen's experiments with the gun-powder engine, Boyle's study of gases and pneumatics, and upon the developments following the experiments of Denys Papin, the Marburg physicist, as well as the contemporary work of Joseph Black on latent heat. A great part of the engineering achievements which have made possible modern industrialism and the indispensable means of transportation have been founded upon the development of mechanics from Galileo and Newton onward. Even the stock objection to the scientific interpretation which centers about the textile inventions from Kay to Cartwright are not as impregnable as earlier supposed. For example, the spindles and belt wheel of the spinning-wheel from which Hargreaves developed his "spinning jenny," as well as the water-wheel which early propelled these machines, were a combination of several epoch-making inventions of primitive scientists. Moreover, from the late eighteenth century to the present time industrial progress has become more and more closely associated with highly scientific technological advances, such as modern industrial chemistry and the remarkable development of modern mechanical and industrial engineering. While there can, thus, be little doubt that even in the past pure and applied science has determined economic institutions, it is certain that this relation will become much more intimate in the future—which, as Professor Thornstein Veblen has insisted, is to be preeminently the technological age in which not only competitive individual economic success but also the "wealth of nations" will depend no longer purely upon superior commercial sagacity, but upon even very slight and extremely refined technological superiority. If, then, we may accept the priority of scientific to economic processes, those who adhere to the views of Bacon, Condorcet, Buckle, Draper and Andrew D. White have advanced one step beyond Feurbach and Marx in the interpretation of history. Finally, to the importance of the history of science in explaining the development of the most potent instrument by which man has progressed through the adaptation of nature to his use, there should be added the unusual disciplinary virtue of the history of science, combining as it does the genetic concepts of history with the exactness and the severe accuracy of the methodology and procedure of the natural sciences.

Again, the study of the history of science from the point of view of historical interpretation adds one more reason for believing in its fundamental significance, namely, its relation to intellectual history and the psychological interpretation of history in general, a field opened by Draper and which has since been cultivated by a number of progressive historians led by Professor James Harvey Robinson.[10] It has generally been recognized that the history of science forms a most vital phase of intellectual history, but this conception is still further strengthened by the newer view, so effectively expounded by Professor Veblen, especially in his "Instinct of Workmanship," and his "Place of Science in Modern Civilization," concerning the intimate connection which exists between the various stages of intellectual development and the changing state of the industrial arts, which are, in turn, dependent upon scientific advances. It would seem, then, that the history of science provides the most fundamental and illuminating background for the study of the history of civilization, compared with which the history of states and political intrigues dwindles to insignificant proportions. It may be, and indeed often is, objected that while science may have created modern civilization, in doing so it brought into being a Frankenstein monster which is rapidly getting out of human control and whose ravages science can do nothing to mitigate. The historian would be the last to deny the serious social and economic problems produced by modern industrialism, but he will probably insist that science alone can point the way out. In support of this view might be cited the achievements of sanitary and medical science, not only in the field of physical disease, but also in its application to social problems and industrial efficiency, and to the apparent progress now being made in the direction of at last securing a rational system of ethics based on sound psychology. This view that science and technology must be the chief agencies that man can make use of in solving the problems of modern industrial society was forcibly stated by the founder of modern *Kulturgeschichte*, Karl Lamprecht, in his address to the general meeting of the Association of German Engineers at Leipzig in 1913 on "The Technics and Culture of the Present Day." After pointing out the general relation between the development of culture and technology he expressed his belief that "it is in the development of technics and modern industry themselves that

[10] The writer has attempted to indicate the progress made in this field in an article on "Psychology and History," published in the *American Journal of Psychology*, October, 1919.

we must look for an expedient for removing the moral and social evils which have been called forth through a brilliant material progress. No superficial suppression of these evils, no administration of charity, no theories, no political revolution can have any lasting effect in attaining this end, but only the moral self-purification of industrial development in itself, and that change to idealism, which must be accomplished in and from the further development particularly of technics."

2. General Neglect of the History of Science by Historians

Aside from a feeling of gratitude and satisfaction over being able to have at one of our Association conferences such a group of eminent scientists, the fact which strikes a historian most vividly with respect to this conference is that at the first session of the American Historical Association on the history of science, three out of four of the formal papers were presented by natural scientists. The situation is all the more significant because this disparity was not due to any determination to go outside the ranks of historians for speakers, but rather was caused by the somewhat embarrassing fact that it reflects very accurately the distribution of the current activity in the history of science, for probably more than seventy-five per cent. of such interest is found among natural scientists. This state of affairs seems particularly strange in view of the fact that there have long been historians and other social scientists who have emphasized the dominating part played by science in the evolution of civilization. Roger Bacon's striking prophecy of the effect of applied science is too well known to describe in detail. Away back in the latter part of the fourteenth century Ibn Khaldun, an Arab savant, definitely rationalized and isolated the history of civilization and emphasized the part played by Arab natural science in the development of civilization. Francis Bacon stressed the importance of intellectual history and had great hopes that general advancement and betterment might be achieved through the application of natural science. Turgot, in his Sorbonne lecture of 1750, showed how progress was dependent upon the cumulative social, economic and scientific advances contributed by each generation and stressed in that way the continuity of history. Condorcet set forth what, at the close of the eighteenth century, looked like an extremely fantastic, but in the light of the last century a rather conservative, estimate of the general progress that might be expected from the application of natural science to human activities.

Henri de Saint-Simon and his disciples, drawn largely from students at the *Ecole Polytechnique*, not only agreed in general with Condorcet, but also advanced a step further by comprehending the vital importance of applied science and in advocating the formation of a social system controlled and directed in its material interests by scientists and engineers. Auguste Comte sketched a philosophy of history in which progress was held to consist in the gradual but sure triumph of the scientific method and procedure over the theological and metaphysical, planned a social system dominated by applied scientists and sociologists and attempted to secure the establishment of a chair in the history of science at the Collège de France. That interesting mid-century socialist, Wilhelm Weitling, would have handed over the complete control of society to a triumvirate made up of the most eminent living physician, mechanical engineer and physicist. Space forbids more than a mere mention of the well-known favorable attitude towards science and its history taken by Buckle, Draper, Andrew D. White, Henry Adams, Thornstein Veblen and Lester F. Ward. Among more recent historians there are a number who have emphasized the significance of science in the evolution of civilization. Some leaders in this movement have been Lamprecht and his associates, Seignobos, F. S. Marvin, and Professors Burr, Robinson, Shotwell, Shepherd, and Teggart in this country. There have been technical historians of science varying all the way from the ecstatic Karl Snyder to the encyclopedic Duhem and the erudite and cautious, if enthusiastic, Sarton, who have urged the importance of science and the significance of its history. The work of Mach, Cantor, Ostwald and Danneman in Germany; of Mieli and Rignano in Italy; of Duhem, Berthelot, Milhaud, Tannery, Picard and Poincaré in France; of Sarton in Belgium; of Merz, Pearson, Shipley, Lones, Singer, Osler, Ross, Thomson and Tozer in England; and of Sedgwick, Tyler, Cajori, Locy, Crew, Karpinski, Henderson, Baldwin, Libby, Hall and Garrison in this country is at least representative of the valuable contributions made to the field of the history of science by natural scientists. In spite of all this, however, one can point to but few European historians, taking the title in its conventional meaning, who have devoted themselves professionally to the history of science, and it seems that Professor Lynn Thorndike is the only one in this country who has cultivated the subject systematically, though one should not forget the valuable monograph of Miss Ornstein on the rise of the European scientific societies. The lure of the episodical,

the dramatic, the biographical and the political history, produced by the inertia in the heritage from older historical interests and concepts and the development of nationalism in the 19th century, has proved too strong for the majority of historians and has seduced them into a grotesque concern with the irrelevant and into a sad ignoring of the vital elements in historical development. It has not been sufficiently emphasized that there are two chief types of superficiality and inaccuracy in history, the first being that which leads to statements made without a sufficiently thorough and dispassionate study of the sources of information, and the second and equally serious variety being that which leads to a failure to concentrate historical investigation upon those topics which seem likely to reveal most clearly the nature and causes of human progress.[11] It is a strange but interesting fact that those who have been most cautious in avoiding the first type of superficiality have been most frequently and fatally guilty of the latter.[12] It would seem that the chief cause of this has been the unfortunate tendency to make states, political institutions and political figures the chief center of orientation and point of departure for historical study and exposition. This has led to a situation in history not widely different from the procedure of a hydraulic engineer who studied the ice on a river and ignored the depth and rapidity of the current, or a geologist sent to make a detailed study of the soil and minerals of a particular area and who satisfied himself with a report on some conspicuous phases of the topography, or who studied a glacier by noting the débris which had accumulated on its surface and ignored the vast mass of ice moving irresistibly beneath.

One is especially reminded of the significance of the history of science, as well as of its relative neglect, when he reflects upon the vast amount of scholastic energy spent upon that chronological succession of guesses as to the nature of reality which is collectively known as the history of philosophy, and also upon the history of the various methods and avenues in which man has gone wrong in attempting to get control over nature and to adapt it to his use, in particular, the vast number of pretentious volumes devoted to the history of religion, the chief mechanism for hoping to attain a supernatural control over the forces of nature—the contrast of which with the

[11] See James Harvey Robinson, "The New History," Chapters I., IV., V., VIII.; and Albion W. Small, *Publications of the American Economic Association*, Third Series, Vol. V., No. 2, p. 178.

[12] See Karl Lamprecht, "What is History?" Chapter I.

scientific approach has been most effectively drawn by the late Andrew Dickson White.[13]

3. Present Status of the History of Science in American Education

The status of the teaching of the history of science in the United States before university instruction was so seriously disrupted by the War has been described in a valuable study made by Mr. Frederick E. Brasch in a paper entitled "The Teaching of the History of Science: Its Status in our Universities, Colleges and Technical Schools," and published in *Science* for November 26, 1915.[14] He studied 352 out of 598 institutions of this type which existed in the country at that time and found that 224 had some course on the history of science and that 128 had none. The first course on the history of science in America appears to have been one on the history of chemistry given by Dr. Theodore W. Richard at Harvard University for the first time in 1890. At practically the same time[15] Professors Sedgwick and Cross at the Massachusetts Institute of Technology began a course on the history of the biological and physical sciences which has been carried on since 1905 by Professors Sedgwick and Tyler. This was the first course in the general history of science given in this country. Perhaps the best known course on the general history of science now offered is that which had been conducted at Harvard, since 1911, by Professor L. J. Henderson. Mr. Brasch found that in 1915 there were many more courses offered on the history of special sciences than on the general history of science, the emphasis being particularly upon the mathematical and physical sciences at the expense of the biological, but he believed that he detected a tendency on the part of these institutions of higher learning to abandon the history of special sciences and to go over to a general course. Most of the larger universities were found to offer both general and special courses in the history of science and an unusual interest in the subject was manifest at the Carnegie Institute of Technology at Pittsburgh. A gratifying innovation of a missionary sort was to be seen in the work of Professor Henderson of Harvard who gave a series of lectures

[13] Of course this statement does not imply any reflection upon the very valuable contribution to intellectual and cultural history made by students of the history of philosophy and religion, but simply attempts to make more clear the relative neglect of the history of science.

[14] *Loc. cit.*, pp. 746–60.

[15] Professor Sedgwick began his lectures in an extra-academic way as early as 1887.

on the history of science to some five middle Western colleges in the spring of 1915. Finally, excellent facilities for detailed investigation in the history of science have been provided for in the John Crerar Library at Chicago, the resources of which were, in part, made public in a bibliography prepared by Dr. Josephson in 1911 and brought up nearer to date in a supplement of 1916. Nor should one forget the promising periodical devoted to the history of science—*Isis*—edited by Georg Sarton, the publication of which was, unfortunately, disrupted by the war, or the various publications edited by Professor Cattell, which have encompassed practically the whole field of science.

While Mr. Brasch's study thus revealed significant beginnings in the history of science in the United States it gave no evidence of any interest in the subject on the part of the historical guild. It is doubtful, indeed, if at that time there was any special course on the history of science offered by historians. Probably the closest approximation was the courses in intellectual history, the history of civilization, and the expansion of European civilization given by Professors Robinson, Shotwell and Shepherd at Columbia, the composite course on the history of civilization offered at Cornell, and certain advanced senior work on medieval education and intellectual interests given by Professor Haskins at Harvard, with some very significant literary activity in the subject on the part of Professor Thorndike at Western Reserve University and Professor Teggart at California. This state of affairs suggests the question as to whether matters should remain ever thus, with the historians generally ignoring the subject, and brings one to the final point in this discussion, namely, a consideration of the type of cooperation and division of labor between natural scientists and historians which is desirable in teaching and writing in the field of the history of science.

4. The Necessity of Cooperation between Historians and Scientists in the Field of the History of Science

It would seem that the manner of teaching the history of science should be determined sharply by the object which it is desired to obtain. It is obvious that there are four chief results to be aimed at, each of which calls for a special course; first, a technical knowledge of the history of a certain special natural science designed to aid experts in arriving at a better command of their particular subject; second, a more general grasp of the development of all the natural sciences which will make clear the manner in which the progress of the several natural sciences has been interrelated and cumulative; third,

an analysis of the history of method which will illustrate the nature and unique character of the methodology of the natural sciences and the manner in which this methodology and technique has evolved; and, fourth, an introduction to the history of intellectual interests and cultural progress which will indicate the part played by science in the history of civilization and will reveal scientific progress in its proper perspective in the general evolution of intellectual interests. It would appear certain that the first three types of courses should normally be taught by natural scientists and the last by historians, though occasionally an alert student of philosophy will be found admirably qualified to give the courses on the general history of science and the evolution of the scientific method. But in both the courses on the history of science and on the history of intellectual interests there should be frank and sympathetic cooperation between scientists and historians. This cooperation, unfortunately, has not generally existed in the past. The scientist, at least in this country, has generally despised the historian when the latter has upon very rare occasions entered the boundaries of natural science and the historian has generally escaped this contempt by ignoring the history of science altogether. This mutual lack of respect and interest and the resulting failure to cooperate has led to a serious loss to both scientists and historians. Scientists, particularly in this country, have exhibited an extremely naïve and uncritical attitude in the matter of handling the historical sources dealing with their subject, works of all varieties of age, accuracy and bias often being used in an indiscriminate manner provided they furnish direct statements of alleged fact, and often some of the most valuable sources of information have been ignored altogether. There also has frequently been displayed a painful lack of power in orderly and attractive narration, which would scarcely be found even in a doctoral dissertation in history.[16] The admitted critical and literary superiority of European historians of science to the American may in part be due to the closer cooperation between them and their colleagues in the faculties of letters and in the field of history. Further, the natural scientist has often seemed to assume that the progress of science has been solely a result of individual investigation, experimentation and discovery, while as a matter of fact the historian well knows that it has been quite as much the product

[16] For a candid recognition of these defects in works on the history of science written by natural scientists, one should consult the article on "The History of Science" by Dr. Louis C. Karpinski in *School and Society*, December 21, 1918. This is written by a natural scientist well grounded in historical methodology.

of circumstances in the general historical environment which have encouraged and made possible scientific endeavor and achievement. In other words, while the progressive historian will freely admit that science has done much to determine the course of historical events he must insist that culture has been quite as effective in conditioning the nature and rate of progress in the natural sciences.

From the historical viewpoint the rather austere scorn of the natural scientist for the historian has sometimes led the latter to risk some excursion in the field of science without having checked up his work by consultation with a scientific expert, but more often it has simply been effective in keeping the historian out of the field, and incidentally in preventing college students of history from having an adequate opportunity to become acquainted with what should constitute, perhaps, the most vital phase of history. Of course it is not meant that historians have always recognized the significance of the history of science and have clamored in crowds for permission to enter the field, being deterred only by the lack of encouragement from scientists. The general body of historians have certainly been as naïve in ignoring science as have scientists in sifting historical sources. What is asserted is that the few historians who have shown an interest in the history of science have not generally met with a warmly sympathetic welcome from scientists. The scientists should recognize that until the history of science is espoused by a large number of historians it can not have its deserved recognition in the academic world and they should cherish, encourage and enlighten the few historians who evince an interest in science with as great care and enthusiasm as a biologist would nurse along the rarest and most interesting sport or mutation which might appear in the evolution of organic life. The growth of mutual respect and the stimulation of cooperation between historians and scientists cannot but be productive of the greatest gain to both. The scientists can receive aid in sifting their sources and arranging their material, while the historians can secure sure and accurate guidance in the technical phase of the subject. It can scarcely be doubted, moreover, that the unquestionably greater objectivity, frankness and candor, and the more earnest search for truth and vital information which characterizes natural scientists, as contrasted with historians and social scientists generally, will have a salutary reaction upon historians. Further than a mere cooperation in research and exposition, historians and scientists should arrange for a better guidance of

their students. Certainly no major student in science should regard his scientific training as well rounded out without comprehending the relation of the history of science to general cultural evolution and the history of intellectual interests and no student of history can be held to be competent in his subject without a decent elementary grasp upon the history of science, for which he may be prepared, if otherwise deficient, by a preliminary course in general science, which should always include some personal contact with and observation of, the exact and painstaking methods of the scientist in laboratory work. It may also be safely asserted that students of science who hope later to teach its history or to write on the subject should during their college course take a thorough course in historical methodology, both in investigation and exposition.

The progress made by natural scientists in teaching and writing in the field of the history of science has already been pointed out and this morning's conference will be welcomed by historians as a harbinger of their closer cooperation with alert students of the newer history. From the historian's side, also, certain significant advances have already been made in this country which to some degree supplants the blank indicated in Mr. Brasch's report on the history of science. Professor James Harvey Robinson in his well-known course on the history of the intellectual classes of Europe has provided, especially in his latest syllabus, an excellent prospectus for a synthesis of the history of science and general intellectual interests, and his point of view has affected many of the younger teachers of history and is evident in the text-books of Breasted, Thorndike, Hayes and Schapiro. Professor Shotwell's famous course on the evolution of European civilization centers largely around the progress of pure and applied science and its reaction upon civilization, particularly its effect upon economic life and activities. It is doubtful if any other American historian, with the possible exception of Professor Robinson, has done as much to direct the attention of the historian to the significance of the growth of science in determining the progress of civilization as Professor Shotwell. Professor William R. Shepherd, in his original course on the expansion of European civilization, has for the first time made clear how far the development of European science in modern times has been due to the reaction of world colonization, exploration and commerce upon European thought.[17] The salutary influence of Professor Burr's teaching

[17] Professor Shepherd's original thesis in this matter is to be found summarized in his articles on "The Expansion of Europe" in the *Political Science Quarterly* for 1919.

and writing in stimulating interest in intellectual history has long been recognized and has permeated the text-book of Professor Hulme on the Renaissance and Reformation, as well as having led to the production of many scholarly monographs in the field of intellectual history. While Professor Haskins has not been usually regarded as a special protagonist of intellectual history no one in Europe or America has done work of a more scholarly nature in this field, and of late he has offered a general course on medieval intellectual history. Further, historians in this country and abroad have at last supplied works that make possible a fairly complete survey of intellectual history. The writing of Breasted, Rogers and Jastrow on the Oriental period; of Zeller, Gomperz, Murray, Zimmern, Fowler, Wissowa and Cumont on the classical era; of Taylor, Poole, Lea, Harnack, Burr, Rashdall, Pactow, Thorndike, Workman and Lecky on the Medieval age; of Brandi, Voigt, Beard, Emerton and Hulme on the Renaissance and Reformation; of Shipley on the science of the seventeenth century; of Shepherd and Abbott on the expansion of Europe; of Fischer, Morley and Stephen on the thought of the eighteenth century; of Benn, Merz and others on the last century; and of Dewey, Royce, Santayana, Faguet, Pearson, Reinach and Dilthey on various topics in intellectual history are only certain conspicuous illustrations of the fertile work done in this field.

There are courses in the history of civilization offered in American universities in which the development of science has been or may be introduced with profit to all concerned. A very significant innovation has been adopted this year at Columbia University whereby all freshmen are compelled to enter a course in contemporary civilization containing at least an introduction to the history of science, sufficient to indicate the scientific progress which lies back of modern civilization. It would seem, however, that, though a fruitful interest in the history of science may be aroused in this way, it is rather too early in the college course for the most effective presentation of the history of civilization. It is probable that the courses in the history of the special sciences should come in the junior year and should be followed in the last college year by the courses in the general history of science and in the history of thought and culture. There might also be mentioned the fact that a general course on the history of science is being offered for the first time this year at Clark College and Clark University under the direction of Dr. Edmund C. Sanford, president of the college, this being especially interesting as illustrating how such a

course may be successfully handled by a student of philosophy and psychology, when possessed of sufficient erudition and a progressive viewpoint. But, important as these details may be, the vital preliminary step is for historians more generally to realize the significance of the history of science and for the scientists to descend to a plane of cooperation, and the details of the division of labor between the two fields and the pedagogical problems will be early and easily adjusted. While at present the scientists show much the greater activity in the history of science, the strength of the conventional in historical interests seem to be weakening and it is not absurd to predict that a generation hence such a book as Merz's "History of European Thought in the Nineteenth Century" will be regarded as containing more pertinent historical information than the "Cambridge Modern History" or James Ford Rhodes, "History of the United States since the Compromise of 1850."

Bibliographical Note.—There is no satisfactory treatment of the problem of the history of science and the method of presenting it for class-room instruction. Valuable suggestions may be obtained from the following easily accessible articles:

Mann, C. R. The History of Science. *Popular Science Monthly*, April 1908, pp. 313 ff.

Libby, Walter. The History of Science. *Science*, November 6, 1914, pp. 670–73. A Function of the History of Science, *Educational Review*, October, 1919, pp. 201–6.

Brasch, F. E. The Teaching of the History of Science. *Science*, November 26, 1915, pp. 746–60.

Sarton, G. The Teaching of the History of Science. SCIENTIFIC MONTHLY, September, 1918, pp. 193–211.

Karpinski, L. C. The History of Science. *School and Society*, December 21, 1918, pp. 741–49.

Sarton's article is especially valuable for its discussion of the requisite knowledge, equipment and pedagogical procedure in teaching the history of science, while Karpinski's is notable for its plea for a more critical method and more comprehensive research in gathering materials on the history of science.

The subject is discussed from the historian's point of view in Marvin, F. S., "Science and History," *Contemporary Review*, March, 1918; Robinson, J. H., "The Relation of History to the Newer Sciences of Man," *Journal of Philosophy, Psychology and Scientific Methods*, March 16, 1911; and Shotwell, J. T., "The Interpretation of History," *American Historical Review*, July, 1913. An excellent recent illustration of interrelationship between the history of science and the history of culture and intellectual interests is provided in the voluminous work of Edmund von Lippmann, "Entstehung und Ausbreitung der Alchemie," Berlin, 1919. See also J. H. Robinson's syllabus, "An Outline of the History of the Western European Mind," N. Y., 1919.

THE ORIGIN OF HIPPOCRATIC THEORY IN SOME OF THE SCIENCE OF THE NATURE PHILOSOPHERS

By JONATHAN WRIGHT, M.D.

PERHAPS one of the first questions the student of history asks, when he comes to grasp the magnitude of the phenomenon of ancient Greece in the evolution of civilization is: When the Greeks met the Persians and the Egyptians in the eighth and seventh centuries B.C., was the rise of Greek philosophy its consequence in the sixth century? Herodotus and Hecatæus relate incidents, which modern archeology has confirmed and expanded, that to some seem to indicate at least an approximation to that conception. The coincidence loses its effect largely when we consider that these authors really began the written history of the modern world. In Herodotus and in the few fragments from other earlier historians we read much of the contact of the people of the Orient and the Greeks. Such records and such traditions do doubtless represent events dating back to the Persian conquests of the Great Cyrus, but we have to depend on another kind of evidence. Ancient papyri, it is true, have been preserved to us which date a thousand years and more beyond that period, but the difficulty in translating the text has only been one of the difficulties we find in ascertaining their meaning and correlation of information thus received, often incoherent in its parts, has not been satisfactorily attained even with the help modern archeology has given us. But from the days of Herodotus we get a fairly coherent story reaching to our own times.

This very coherency and the more or less unbroken continuity in our older historical conceptions have conferred a perhaps exaggerated importance on the first meeting of the Greek men of brass in the Delta of the Nile which Herodotus relates (II. 152). From those literary sources now open to us, even isolated as they are in the gloom of an antiquity which Herodotus has not dispelled, we get enough to convince us of the activity in the intercourse between the shores and islands of the Mediterranean and the oriental hinterlands. The Persian, the Egyptian, the Assyrian surges of political power which swept, at least in their influence on the types of civilization, across the Ægean to its islands and the headlands of Europe, we may well believe lighted foci of culture which were not extinguished when the brown people surged back again, but we can no longer avoid the conviction that throughout this vast

period the general underlying culture of the whole Mediterranean basin, extended far inland on the continents of Asia and Africa, was more homogeneous than certain schools of historians were once wont to admit. This general principle, at which we have arrived, has to be kept in view when we study the vexed question of the intrusion of the northern nations. I may seek the excuse for avoiding the conclusions at which German pre-historians have arrived, on the plea that no evidence credited to them is liable to be received with favor at a time when there is still felt the heat of battle which has overwhelmed their countrymen and the German historians themselves, to whom the major blame has been attached for the prevalence of that imperial spirit which has brought such unexampled woe upon this world of ours. The facts elicited can not be ignored but they are very far from being all attributable to teutonic research. The deductions from them we have no reason to treat with the same respect.

Although Ridgeway[1] leans upon many facts brought to light by German archeology and is quite evidently influenced to some extent by its conclusions, although he has never written the second volume of his "Early Age of Greece," it is said because the first volume published nearly twenty years ago would have to be rewritten, we may regard as correct the view he entertained at that time that new blood has been always coming into the Mediterranean basin from the North, trickling down through the Balkan gorges it is true, but coming in larger streams from the Black Sea region. Upon this latter route we need only fix for a moment our attention with the thought that both a priori assumption and such historical and archeological evidence as we have points to the probability, if not the certainty, that at certain periods, from causes by no means clear, this steady trickling penetration has been supplemented by repeated invasions of large bodies of red-haired and blue-eyed men which, for a few generations, over varying extents of the Mediterranean area, have submerged if not exterminated the brown-skinned races. These we call indigenous because back of their time we know only the men of the caverns and the Ice Age. Such a preponderating northern blood may have existed in many parts of the Ægean area at the time of the Trojan war. Its existence may not have been unconnected with that migratory mass which, we have come to believe, at a period earlier than that swept through the foothills and mountain passes of the Himalayas into India. The only remark that remains to be made as to the deductions drawn from the indica-

[1] Ridgeway, William, "The Early Age of Greece," Vol. 1, Cambridge University Press, 1901.

tions of these ancient currents of migration is that they have ignored not only the difference between biological and social heredity, but the difference between that part of biological heredity which tells for the persistence of the physical characters of a race and that part which exhibits its mental and moral characteristics. Blue eyes and red hair and skull configurations and stature may indeed die out under the change of environment from the Danube to the Ganges, but until we have better reasons for thinking the contrary, we may refuse to think that necessarily means the death of those invisible and imponderable psychological traits of race which influenced the later course of Greek civilization.

It is not necessary for our purposes to expand these considerations as to the more or less doubtful conclusions, at which history and archeology have arrived in our days, of the relation of the earliest Greeks to neighboring peoples. The only essential thing to keep in mind is the extreme probability that, however much more forcible the impact of the Persian empire upon the Greeks was than the oriental influence which had existed before or after the time of Cyrus and his immediate successors, there were further back than history reaches constantly open channels of commerce and of thought along which ideas may have travelled between east and west. Many years ago a facile Italian writer, De Amicis I think, declared that at Constantinople over the bridge across the Golden Horn ten thousand people crossed daily, but an idea only once in ten years. To Mr. Kipling we owe the despairing apothegm, East is East and West is West; without a better bridge for ideas between them the future is dark indeed for what Mark Twain called "the damned human race." Despite the fact that De Amicis was thinking, in the complacent way we Westerners of recent centuries are accustomed to fall into, of the flow of ideas towards rather than from the rising sun, we must give this train of thought the weight, in a discussion of our own topic, that is its due.

Now occidentalism may not mix well when poured into orientalism, but we need not be too sure that orientalism can not be any more readily poured into occidentalism. Pharmacology teaches us that liquids in manipulation act that way sometimes. To be conscious that Christian cults, animated by all that Western energy and presumptuous vanity can put behind them, do not hold their own even with Mohammedanism, when the missionaries withhold their Christmas sugar plums, is a way of realizing the truth of this admixture process. It still reminds us of the old doctrine that culture has always

traveled with the sun, that orientalism is constantly infiltrating the boasted civilizations of the West. This view does not lend itself very easily to scientific analysis, because it is one which involves so many imponderables. At any rate this rather vague feeling out of the evidence will serve to remind us that perhaps the so-called Aryans did not carry with them a current of Kultur into the heart of the East but doubtless, as has always been their habit, left a trail of blood where they passed, as of late with the Bible in their hands.

As I understand it archeological and philological research has demolished the view that the Susrutas are the origin of some passages of the Hippocratic books. Certainly no one on making the comparison can fail to see that one is surely the source of the other. Native Hindu scholarship vigorously insists on the priority of the culture beyond the Hindu Kush, and Hoernle[2] is not by any means entirely convinced to the contrary in a general way, but fails to lend any sympathetic support to the antiquated view that Hippocrates got much of his doctrine from the Ayur Veda of Susruta. We are inclined to flatter ourselves with the belief that the physicians in the train of Alexander carried Hippocrates to "Susruta." This may well be so and still we can not dispel the strong impression that the roots of Greek Nature Philosophy were deep in oriental soil and irrigated by oriental thought. For the present we may however safely lay the flattering unction to our souls, unmistakable as this seems to be, that their chief efflorescence began in an atmosphere of civilization created by the Greeks of the Golden Age.

There are one or two considerations still to be taken into account, in a study of the antecedent cosmic relationship of the rise of the Greek nature philosophy, to which I have not alluded. One has to do with Space and one with Time. One is a geographical consideration and the other a chronological one. It has been pointed out that if you follow the space from the 30th to the 36th parallels of north latitude round a globe representing the earth you will find in a belt measuring north and south some 350 miles the deltas of the Nile (32°), the Euphrates (36°), the Yangtse Kian (30°) and the Mississippi (30°). In prehistoric times there arose mighty civilizations on the alluvial deposits of these rivers, the wash of the continents of Africa, of both sides of Asia separated by the dividing lofty peaks of the Himilayas, and of America. There animal life was easily maintained and sheltered by various configurations of land and

[2] Hoernle, A. F. Rudolf, "Studies in Ancient Indian Medicine," *Journal of the Royal Asiatic Soc. of Great Britain and Ireland*, 1906, p. 915; "Studies in the Medicine of Ancient India, Pt. 1, Osteology or the Bones of the Human Body," Oxford, Clarendon Press, 1907.

water. The richness of those alluvial deposits, extending far up the valleys of the rivers, nourished the beginnings of the human race. In the perimeter of the influence of these conditions cultures flourished, which in the course of many thousands of years have been pushed far beyond this favored strip around the earth. Miletus, Cos, Colophon and the Ægean Islands, on or close to the shores of Asia Minor at the debouchments of the Asiatic caravan routes and in the shelter of ports suitable for the commerce of antiquity, are the spots where arose and from which was dispersed throughout the Greek world the science of the nature philosophers.

As to time, if we use as beacon lights of the infancy of science, not yet divorced from religion, the names of Zoroaster (660 B.C.), Confucius (550 B.C.), Buddha (560 B.C.), Thales (640 B.C.), Pythagoras (582 B.C.) (and whom could we better choose to show us when the human mind first began to work coherently?) the first thing that strikes us is the comparative simultaneity with which they flare up in the abyss of time from the Hoangho to the Cyclades. What does it mean? The first persistence of written records, perhaps? Take a map and you will find these men dwelt on the 35th degree of north latitude strung along a stretch of 100° of longitude. We get a glimmer of intelligence, it is true, of cosmic law; it is not exclusively one of geophysics, but a far more mysterious one of psychomental evolution, curiously affiliated with the measurement of time. To say that this phenomenon is due to the fact that there was a simultaneity in the preservation of the records of the thoughts of these men would be as mysterious as to attribute it to the simultaneity of the birth of modern mental processes itself. We need to concern ourselves further with geo-physical processes, but it concerns us to realize that the evolution of thought is also one of cosmic evolution. It has had its marvelous sequences and we know the Ionian philosophy must have had its antecedents, mysterious as they appear to us.

It was not alone along the mouths of the Euphrates and the Nile the water receded and discovered beneath it to the gaze of the philosopher the soil to which it apparently had given birth. The steaming vapor arose elsewhere into the air and elsewhere air seemed to have its birth from water. When the water fell from heaven on the Mesopotamian plains or spread from the rising Nile over its banks it gave birth to life itself, still a marvel to men from less favored regions who see it for the first time springing in the magic of the elements from fruitful prairies. So we find Thales saying water is the primeval element of the universe from which all things else spring, not the living vegetation alone and the animal life that feeds on it, but

the soil too. We can not yet fathom the chronological mystery, but we see the basis of the nature philosophy in geophysics at least. There is every evidence in the most ancient epics that Thales did not first formulate a theory, so supported by the induction from fact, for ages open to the observations of all delta dwellers. Water was worshipped in Babylon. It is not difficult to find this also in the Zend Avesta, perhaps contemporaneous with the life of Thales and in the Rig Veda vastly older than the Ionian philosophy. Some time some editor will allow me to collate that evidence, but there is no space for it here.

Diogenes Laertius[3] is not only a later but a less capable authority than Aristotle in the discussion of the philosophy of the Nature philosophers, but there is a passage to be found in his Lives and Opinions of Ancient Philosophers which serves our purpose better.[4] After referring (VI.) to the fact that the Chaldeans study astronomy and the soothsaying of the Magi and "deliver accounts of the existence and generation of the gods saying that they are fire and earth and water" and after referring to their belief in omnipresent phantoms in the air, he credits Thales with having discovered and invented about all things then known. Besides "he asserted water to be the principle of all things and that the world had life and was full of dæmons." We get at once in the old philosophers the pantheistic belief of primitive man from a record in an age when it was no longer the exclusive point of view, but we get something else, the affiliation of Thales with the lore of Babylon and the orient, despite the fact that Hermippus is quoted as referring to Thales rather than to Socrates the thanks he gave to Heaven that he was a Greek and not a barbarian. Thales too dabbled in the astronomy and astrology of the Magi and is credited with predicting an eclipse, which Murray[5] ventures to credit with the date May 28, 585 B.C. Some said he was a Jew, which is

[3] Diogenes Laertius, "Lives and Opinions of Ancient Philosophers," tr. by C. D. Yonge, London. Bohn, 1853.

[4] I do not wish to clutter up this essay with references and discussions aside from the pursuit of the end I have in view, the relation of the doctrines of the nature philosophers to those of Hippocratic medicine, but I can not forbear alluding to the now ignored Bayle (Dictionnaire Historique et Critique, Amsterdam and Leyden, 1730) who has given by far the best summary of the ideas which in antiquity clustered around the traditions and the philosophy of Thales, if read in an intelligent way. It gives an aperçu far enough removed from our day to be divorced from many of the ideas which environ us and to allow us an insight not to be gained from much more recent historians of Greek thought.

[5] Murray, Gilbert, "Rise of the Greek Epic," 2d ed., Oxford, Clarendon Press, 1911.

doubted,[6] others that he was a Phœnician, but Windelband,[7] accepting the evidence advanced by Zeller, declares he was of a Greek family which had migrated from Bœotia to Asia Minor. However that may be, we find it is said he accompanied Xerxes's army in the capacity of an engineer and he measured the height of pyramids in Egypt by their shadows on the sand.

Much of this may be idle tales, but they are old ones at any rate and rested doubtless on a basis of knowledge of his intimate association with the Persian conquerors of the world. The answer, then, as to the reality of Persian influence made by the student of history to whom I alluded at the start must be in the affirmative, but that oriental influence on the philosophy and science of the Greeks began with Cyrus's short-lived though mighty empire can not for the moment be entertained. The Medes and Persians were upstart mountain peoples who swept down on Nineveh and Babylon and their hoary civilization. The empire of the King of Kings stretched from far beyond the Indus to the rushing tide of the Hellespont, and we can scarcely forbear the belief that many an idea, during a generation or two at least, must have crossed the Golden Horn, going west, 2,500 years before De Amicis wrote his book on Constantinople. Routes of travel became secure and so smooth messengers passed over them at fabulous speed. Relays of horses and inns for horse and man bound distant provinces together. Still, great empires had flourished for thousands of years in Mesopotamia and Cyrus built his on the ruins of Nineveh and Babylon and we find Thales in contact with Babylonian ideas and, if not looking upon water with the reverence of the Magi, regarding it from the standpoint of philosophy as the elementary body of the world, but we may be sure Greece knew of Babylon before the rise of the Persian power. Anaximander, who seems to be the first Darwinian on record was the contemporary of Thales, having supposedly been born after him and to have died before him, need not detain us except to take note that in his advocacy of mutational ideas he seems to have antedated Heraclitus by a few years, but the latter in his obscure and striking phrases impressed it more emphatically on subsequent philosophical thought.

We must therefore lay this aside for a moment and seek the origin of the thought of Anaximenes in accepting the air as the primordial element. This is rather difficult. Indeed it is not at all clear how the air came to be regarded as a materialistic con-

[6] Burnet, John, "Early Greek Philosophy," 2d ed., London, Black, 1908.

[7] Windelband, W., "History of Ancient Philosophy," tr. by H. E. Cushman, 2d ed., New York, Scribners, 1906.

ception before the time of Empedocles, unless some demonstration of an objective nature was familiar to men before the latter referred to his klepsydra experiment, but after all that is a mere landmark for us and is of no significance beyond a suggestion of a state of knowledge which may have been long in existence. Thales, Anaximander, Anaximenes were all Milesians and contemporaries, the latter being regarded as the younger. For anything we know of their lives there is nothing to contradict the assumption that they were acquainted with one another and their doctrines like their lives must have been contemporaneous in a relatively small area inhabited by the Asiatic Greeks. They must have lived in approximately the same atmosphere of thought, subjected to the same cosmic influences, yet we find Thales looking upon the water as the elementary unit and Anaximenes, disagreeing with the mutational ideas of his elder, Anaximander, differing from the authority of the still older Thales by the prominence he gave to air in the part it played in the universe. We can find no clue to this except in the supposition that the air in the thought of Anaximenes was the rationalistic inheritance received from the primitive thought of the soul. While the invention of the word pneuma is ascribed to Herodotus we may look at the doctrines of Anaximenes as introducing into science concepts received from ideas of men who had long since identified the soul of man with it. I can not think that the vapor of Thales's water ascending above the steaming mud flats of the marshes and vanishing into the atmosphere could have put that vigor into the belief in the potency of air which we recognize in the theory of the pneuma as found in ancient medicine. The water, the moisture in its influence on vegetation, was an ever-recurring incentive to the subsequent doctrine of the humoral theories but we must find support in the primitive ideas of the soul for that stimulus which we equally recognize in the doctrine of the pneuma. In a number of essays[8] I have developed this affiliation and I need only allude to it here. I take however this occasion to remark, as a preliminary to a like development of the history of humoral ideas, that they owe their expansion and the vigor with which they flourished not alone to the philosophical ideas of Thales in regard to water, but quite as much to the magical form they took in Babylon, which always lends itself so readily to the propaganda of belief.

Trivial and absurd as some of the statements attributed to Anaximenes we see in the form of the statement of his philos-

[8] "The Soul and the Breath," *New York Medical Journal*, July 20, 1918; "The Blight of Theory on the Acquisition of Anatomical Knowledge by the Ancient Egyptians," Ibid., Dec. 7, 1918.

ophy which has come down to us[9] something significant to us in the opening phrase of a discourse on the air. "When it is very attenuated fire arises . . . a sort of rarefaction of the air." Now we have no explicit data as to his birth and death, but as has been said, he seems to have had personal converse with Thales and Anaximander, who both died probably within ten years of 550 B.C. All of these, we remember, were born at Miletus, which had commerce on every trade route of the Near East and had sent out colonies along many of them. It was not destroyed by the Persians until about 500 B.C. The birth of Heraclitus at Ephesus is sometimes fixed at 535 B.C. As Anaximenes, like so many of these old men of science whose lives had to be stretched out to conform with traditions of various events widely separated in time, was supposed to have been then alive, his ideas at least must have been familiar to Heraclitus, for it is said Anaximenes was an instructor of Anaxagoras in 480 B.C. At any rate when Heraclitus had arrived at maturity doubtless the doctrines of the elder man were well developed, with their implication of fire as springing from the air, which differed under the influence of its environment in rarity and density. Back of this physical conception of fire and heat in its rationalistic affiliation with the air lay the impetus of Zoroastrian magic or religion. Thus it seems more than possible that the views not only of Thales and Anaximander and Anaximenes but those also of Heraclitus and Parmenides had not only much in common but a common basis in magic. It seems to me then that the idea which Lewes,[10] among the first of the modern historians of the Greek nature philosophers, had, that there was some metaphysical doctrine behind them which held them together, was fully justified. No fact or speculation is saved from oblivion unless it falls on ground which has been prepared for its germination into a larger life.

The views of Heraclitus too doubtless found a more ready acquiescence, because his sayings were mystical and obscure to such an extent that a thousand years later he even secured the approbation of Clement of Alexandria in not trusting alone to observation and experiment. He quotes him as saying that "eyes and ears are bad witnesses for men, since their souls lack understanding." His further cryptic saying resembles that of Anaximenes so much we may doubt if tradition has not confused the two. Heraclitus is quoted[9] as saying "the transformation of fire are first of all, sea; and of the sea one half is

[9] Bakewell, Charles M., "Source book in Ancient Philosophy," New York, Scribners, 1909.

[10] Lewes, G. H., "Biographical History of Philosophy," 2 vols., Appleton, New York, 1857.

earth, and the other half is lightning flash. All things are exchanged for fire and fire for all things, as wares are exchanged for gold and gold for wares." We are warned by Burnet[6] not to put too much trust in these reports derived from Sextus Empiricus and indeed we find Anaximenes quoted, as above, saying fire is but attenuated air which when it is condensed is "wind, then cloud, then when more condensed water, earth, stones. . . . All things are generated by a sort of rarefaction and condensation of air." The latter saying explains to us more fully the development Diogenes Apollonius gave at Athens to the air. We have Diogenes Laertius[8] for authority that he was the pupil of Anaximenes and was once at Athens. At any rate whatever may have been the exact date of the life of Diogenes Apollonius we arrive at the time or near the time of Hippocrates and we can perceive the atmosphere into which he was born. We can better understand the caution he exhibited and even the hostility, akin to disgust, which he exhibited in the Book "On Ancient Medicine" when he repelled the theories of the Nature Philosophers. Socrates, some years his elder, in his way joked about it. Diogenes Laertius relates that Euripides once gave Socrates a "small work of Heraclitus to read, and asked him afterwards what he thought of it, and he replied: 'What I have understood is good; and so I think what I have not understood is; only the book requires a Delian diver to get at the meaning of it.'" I am sure some of us would agree that Heraclitus was not only "the obscure," but the obfuscated, and thus earned the sympathetic notice of Clement.

With this exposition of the cosmic analysis of Thales, Anaximander, Anaximenes and Heraclitus we have of course by no means exhausted all that could be said of their mental activities nor have we quite exhausted all that is desirable to say of the sources accessible to us from which Hippocrates might have drawn his ideas. Socrates, we see from another acount, was interested though not much enlightened by what Heraclitus had to say, but Plato's works bear indubitable evidence of the influence upon the author of the theories commonly attributed to Heraclitus. Between the Master whom his pupil made immortal, between Socrates and Plato in age stood Hippocrates, more concerned than either of them with the river of life which the physician never finds the same.

Xenophanes, born 570 B.C. at Colophon, said to have been a disciple of Anaximander, was driven by the Persian War, which destroyed Miletus and so many of the other Greek cities of Asia Minor, from his home and made a beggar, a peripatetic impecunious scold, always ready for a jibe and a jest, and interested in the earth as the primary element of all things. Some

one told him that eels lived in hot mud. "Ah well," he said, "we will boil them in *cold* water." To him science owes that healthy skepticism which refuses belief of even the obvious. He was said[11] to be the friend of Hippocrates, though I can not reconcile that to his having been the pupil of Anaximander, nor with his having been born in 570 B.C. when Hippocrates was born in 460 B.C. He is even credited with having written the Hippocratic treatise "On Ancient Medicine," which is better chronologically. We can conjecture that Hippocrates owed to him the caution with which he looked upon theories exhibited in other books, usually those regarded as "genuine," whose spirit of reserve is in such contrast to that of "The Winds," sometimes said to have been written by Diogenes Apollonius, when the air is the cause of everything. Xenophanes at least supplies us with the complement of the four elements of the unitarian philosophers. "All things come from earth and all things end by becoming earth. For we are all sprung from earth and water."

Thus far I have only outlined those matters of interest which are in line with subsequent thought in Hippocratic Medicine, leaving aside other matters scarcely less essential in a study of the broader aspects of philosophy. To this world of Nature Philosophy Empedocles is closely allied despite his intimate connection with the history of Hippocratic Medicine for we are already in the age of Hippocrates when we reach Empedocles, who is supposed in one chronology to have been but ten years older than the Father of Medicine. The theory of the special senses developed by Alcmaeon and Empedocles, is dependent on atomic doctrine for its very existence, yet they were certainly both of them older than Democritus with whose name atoms are usually associated. The physiology of the senses plays but very little part in the literature of the Hippocratic Corpus. The special treatise of Theophrastus[12] on the Senses, and the historical account of Beare[13] in modern times are so condensed that an account of the matter extracted from them could be further compressed only at the expense of the elimination of much detail in which much if not most of the interest resides. It is quite out of the question to attempt such an exposition here but at any rate from what has preceded we are in a better position to measure the originality of Empedocles in his

[11] Gomperz, Theodor, "Greek Thinkers," tr. by Laurie Magnus. New York, Scribners, 4 vols., 1908–1912.

[12] "Theophrastus and the Greek Physiological Psychology Before Aristotle," tr. by George Malcolm Stratton, London, Allen & Umvine (?), 1917.

[13] Beare, John I., "Greek Theories of Elementary Cognition from Alcmaeon to Aristotle." Oxford, Clarendon Press, 1906.

relation to other implications of Nature Philosophy. It was not in inventing another unit for a sole element. It was in further development of the theories plainly antedating his own life span. It was in the greater precision of the combination of the elementary constitutents of all things, earth, air, fire and water. Of his predecessors Alcmæon, the Pythagorean, is supposed to have been his master as Leucippus was thought to have been the teacher of Democritus, a coeval of Hippocrates (b. 460 B.C.). In the sense however that these men taught their pupils anything new they were not their masters,—the ideas which had their birth in ages long past were apparently only carried to their logical or illogical conclusions by Empedocles and Democritus.

The views of Alcmæon, much less those of Empedocles, especially as to the senses, could not have been entertained for a moment without the appreciation of the minute divisibility of matter. We can even suspect this conception was the chief advance of the human mind which sapped the foundations of primitive man's belief in the dæmonic etiology of disease. Whatever weight this thought is entitled to, we can easily realize that a mighty obstacle to the advance of ethics was rolled from his path when man came to realize he could not escape from evil by transferring evil to some one else. Primitive and even much later man often acted on the assumption that if he passed on his disease to another he must necessarily thereby get rid of the devil that was gnawing at his own vitals. Bacteriology has got rid of that difficulty by inheriting from Leucippus or his unknown forerunners the doctrine of the minute divisibility of disease devils in the body. What is the good of passing on this sort of spawn to another? Plenty more must be left behind. The minute divisibility of matter had more to do with the doctrines of Alcmæon and Empedocles and even more to do with modern bacteriology than they had to do with the physiology of the Hippocratic books, yet in the doctrines of the pores, a necessary corollary of atomic apperception of sense objects, we find ample reason for alluding to Leucippus and Democritus in the history of Hippocratic, Platonic and later physiology and therapy.

Pythagoras lies a little apart from our interest, not only because his strange preoccupation with numbers did not have much influence upon subsequent medical history in the time of Hippocrates, but I am personally quite unable to understand either the strength of his propaganda in antiquity or the phenomenon of its origin. We can as a rule run down or rather ascend the currents of thought to their sources in the emotions or the comprehensible aberrations of reason of primitive man,

but, though the invention of numbers had its magical affiliations, this was very long indeed before Pythagoras brought back to Crotona the doctrinal teachings of the orient and very long after men on the sea coasts were accustomed to figures and to figure. The mystery which surrounded magnetic iron, or radium or any other new thing is sure to attract an eager crowd of the credulous longing to be astounded, and of those eager to do the astounding, but this sort of mushroom cult produces no such extended and long persisting attention as the doctrine of numbers spread by the Pythagorean sect to Plato and through Plato to the Neo-Platonists and to mediæval thought. Pythagoras however was the teacher of Alcmæon and though the latter is said[7] to have stood aloof from the number theory, he doubtless had from the chief of his sect the idea, subsequently and to this day pervading all medicine, that health is an equilibrium of forces, an idea in consonance with that of harmony as a general principle which rules cosmic affairs. How far Alcmæon anticipated Empedocles in rejecting unitarian ideas of the elemental constitution of matter and its inevitable influence on the unitarian conception of the etiology of disease, we may perceive, if we accept the fragment[14] attributed to him. "The preservation of health is the equipoise of forces, of the wet, dry, cold, warm, bitter, sweet, etc., the predominance of one alone produces disease. The activity of one of the opposing principles works harmfully. Indeed cases of disease, so far as the causes are concerned, are to be traced back to the preponderance of heat or cold, dependent upon too much or too little food, affecting the blood, the brain or the marrow; but diseases also arise from external causes, from certain waters or regions, or from fatigue, or famine or the like." This reminds the student of Hippocrates at once not of "Ancient Medicine" alone but of the "Airs, Waters and Places."

We are unable to trace the theory of pores further back than Alcmæon, but wherever the atomic division of matter, especially in its application to the beginning of physiology of the body of men and animals, first began to engage the thoughts of men, the pores for them to enter must have arisen in the speculations of the human mind. If Leucippus was the teacher of Democritus who was born in 460 B.C., he must have been rather the contemporary than the teacher of Alcmæon who was the pupil of Pythagoras; teacher of Democritus who was coeval in birth with Hippocrates he could scarcely otherwise have been. In fact we know nothing of the birth or birthplace of Leucippus. According to Aristotle he is removed to a date as early at least as the old age of Pythagoras whose birth is placed about 570 B.C.

[14] Diels, Hermann, "Die Fragmente der Vorsokratiker," Berlin, 1903.

These dates are most of them irreconcilable with so much that is said about the doctrines attributed to the various personages that we are lost in a maze, but we have good reason to doubt that the ideas of pores in and on the surface of the animal body to receive the atoms of Leucippus originated with Alcmæon. Different sizes and shapes of these, which, of course reminds Gomperz[11] of the theory of his countryman Ehrlich, given off from the object seen, heard, smelled, tasted and even felt serve to complete rather than to originate or even elucidate the thought supplied as a basis of the theory of perceptions.[13] It no doubt also opened the way for Empedocles to form later his teachings of respiration and perspiration through the tissues and their external covering. It supplied Plato with the thought of his wonderful scheme of the network of the body. Its affiliation with what histology has revealed to us of the minute structure of the connective tissues is easily demonstrable and is as striking an example of how the generalizing power of theory outruns the knowledge of facts as that of the atomic theory itself. Theory so remote in time as this was forming a soil in which future science could find a suitable place for accepting facts which otherwise would have been lost with myriads of others less fortunate, which have been exposed and perished in the immense stretch of time which has since intervened, for the want of a proper environment.

Having given us the most plausible definition of the etiology of disease, having advanced and expanded a preexisting atomic conception of matter, Alcmæan, according to the records, was the first to declare and possibly to demonstrate by the dissection of animals that the brain is the sensorial center and the origin of the nerves. I think Burnet[6] has not sufficient evidence to show that Hippocrates himself, if we accept Littré's classification of the Hippocratic Corpus, grasped this view at all, though Plato[15] evidently was influenced by it in placing the higher, the rationalistic part of the soul there. This teaching of his elder made no impression on Empedocles and Aristotle totally and specifically repudiated it.[16] Galen established it more firmly, for this fact did not perish, since it is evident in some of the so-called spurious books of the Hippocratic Corpus. We recognize in Alcmæon, from the little tradition has left us, a mind commensurate with that of Hippocrates himself. It is impossible to take up here the physiology and, in the broader use of the term, the cosmic theories of Empedocles, for I look upon them as indissolubly connected with Hippocratic medicine itself.

[15] Plato, "Timaeus," 73.

[16] Aristotle, "History of Animals." Lib. II, Cap. 4.

THE ECONOMIC IMPORTANCE OF THE SCIENTIFIC WORK OF THE GOVERNMENT. II

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COOPERATION BY THE GOVERNMENT IN INDUSTRIAL RESEARCH AND STANDARDIZATION

The success of industrial research work by the government has been amply demonstrated. That government laboratories have done scientific and technical work of the highest quality, and done it efficiently and acceptably to the public, is generally admitted by those well qualified to speak. Their efficiency will not suffer in comparison with that of commercial organizations. It is doubtful if any commercial organization could approach the performance of government laboratiories if the Board of Directors had maintained an inflexible and inadequate salary scale for all the more responsible technical and administrative positions as the government has done.

Scientists and engineers in the service of the government appreciate the opportunity of carrying on researches and constructing public works in the public interest, and of being able to make investigations and publish results unfettered by commercial considerations. In consideration of these advantages, many are willing to remain in the government service at less salary than could be earned elsewhere. Until recently the government has been able to retain its able men on the average nearly as well as the colleges and the industries. During the past few years, however, circumstances in this respect have changed. While the cost of living has nearly or quite doubled, and salaries in the industries and in many of the colleges have been considerably increased, government salaries have increased very little and in the higher grades not at all. The result is that in many cases men can not support their families, and are obliged to seek employment (or accept employment offered or urged upon them) at a living salary. In many cases men who are making a splendid success and have regarded the government service as their career, leave their positions from necessity and with the greatest reluctance. Often these positions can not be filled and the work suffers or ceases altogether. It is believed, however, that this condition

will not continue indefinitely. A readjustment of the salary scale must be made if the government is to have the services of a competent and permanent staff to conduct its scientific and administrative work. In view of the splendid success achieved in the past, it does not seem possible that this essential part of an effective government will be allowed to disintegrate and go to pieces. Industrial research conducted by the government with the active cooperation of the industries, and in some cases of the states, may be made even more important and successful in the future than in the past; for it is needed now more than ever, and is appreciated as never before.

In order to give a more concrete idea of the practical usefulness and economic importance of research and standardization, a number of special cases will be cited in the field of the Bureau of Standards. These cases are chosen partly because I am especially familiar with the work of this Bureau, and partly because there appears to be at this time especial need of the kind of constructive scientific research in the manufacturing industries which it is one of the functions of this Bureau to carry on. Equally striking examples could be cited in Agriculture or Mines or other lines of government research.

Standardization and Research in the Building Industries

For several years recently the building of homes has been almost suspended, and now there is a scarcity of houses in many cities. Meantime the cost of building has increased enormously, due to the greatly increased cost of labor and materials. In consequence real estate and rents have risen beyond all precedent. There never was a time when it was so necessary to use building materials intelligently, to reduce waste, to simplify design and construction, to standardize dimensions and methods, to make parts interchangeable and fit together readily. so as to economize labor and reduce costs. If standard specifications could be prepared and agreed upon in a much larger number of cases than has yet been done it would greatly facilitate the work of architects and builders; and if building methods and the requirements of city building codes could be thoroughly studied and revised this also would aid in reducing building costs. It seems probable that hundreds of millions of dollars could be saved within a few years if a comprehensive and intelligent study were made of all phases of building, including fire prevention and the plumbing, heating, lighting and hardware equipment of buildings. It would also re-

duce the cost of repairs and maintenance of these buildings; partly because deterioration would be slower and failures would be less frequent, and partly because repairs would be easier and cheaper to make. The government would do only a portion of this work of research and standardization, as many engineering societies, industrial organizations and manufacturers would cooperate. But the government should take the lead, and do an important part of the research work, and nothing which the government could do would be more useful and constructive, or would be more appreciated by the building industries and the public. Standardization work of the kind suggested has great educational value, to architects, to builders, to manufacturers, to jobbers, to building owners. It would tend to improve the design and methods of building, and would simplify many building problems as well as lower the cost. Is there any good reason why such a constructive program of cooperative study should not be undertaken? Can the people of this country afford to go on without it under present conditions?

Standardization and Testing of Automobiles

The automobile industry is one of the most important of our industries, and motor vehicles of all kinds play a most important part in the business and social life of the people. Several billions of dollars are expended each year in the purchase and maintenance of motor vehicles. Great improvements have been made in recent years in their design and construction; on the other hand, the quality of materials and workmanship has in many cases gone backward. Much progress has been made toward the standardization of the materials and parts of motor vehicles, and great credit is due to the automobile industry therefor. But there is great need for further systematic study and the preparation of specifications and tests, and the encouragement of testing so that purchasers may know better what they are buying and selling agents may describe their machines more precisely. The interests at stake are so enormous, and the possibilities of service to the public are so great, that it seems imperative that more should be done by the government to assist the industry in its great task.

Gasoline and Manufactured Gas

Gasoline is getting scarcer and dearer every year, and yet not enough is being done in a systematic way to show how to

economize in the use of gasoline. A thorough investigation of carbureters and fuels, and certified tests of the performance of all makes of automobiles, would be a great value in economizing in the use of gasoline, and giving the public as much service as possible for a given expenditure. The Bureau of Mines and the Bureau of Standards have studied different phases of this question, but neither has been able to do as much as should be done. With millions of automobiles in daily use, and gasoline constantly rising in price and deteriorating in quality, can the public afford to have the government fall short in a matter of so great economic importance, and of serious personal concern to so many?

Manufactured gas is used for cooking and lighting by many millions of people and by the industries for scores of uses. A large part of this gas is made by the use of petroleum oil to enrich blue water gas of low heating value. Recently this gas oil has become scarcer and dearer, and it threatens to become still more expensive and perhaps impossible to get in sufficient quantity. That will necessitate the use of lower grades of oil, or the production of lower grades of gas, or a change of manufacturing equipment at enormous expense. Individual gas companies can not study so fundamental a question comprehensively; individual cities or states can not assume the responsibility of solving the problem for the entire country. The proper agency to take up this question is the federal government, with the cooperation of the gas companies and the oil companies and the state and municipal authorities. Such a comprehensive and constructive study would be of great value and would have the sympathy and support of all the important interests. It should include the matter of raw materials, manufacturing methods, and the relative usefulness of the various grades of gas that can be produced.

Public Utilities

The government should cooperate actively with gas and electric and railway and telephone companies in the study of the many engineering questions involved in rendering good service to the public. The changed economic conditions of recent years have made it impossible for many public utility companies to meet expenses. In some cases they have gone into the hands of receivers, in many other cases they escape by putting up rates. But advancing the rates beyond a certain point reduces the sales and does not give a proportionate

benefit. The public in the end must pay all the cost, and the public is vitally concerned in having efficient and economical management of these utilities. If the government could help the companies to help themselves, it would often be better than an increase in rates. The government could render a service of immense usefulness and importance by studying the problems of the public utilities and helping the companies to secure more efficient operation and a better understanding by the public of their difficulties and their needs. The utilities are a special kind of partnership between their owners and the public, in which the owners agree to furnish the plant and the service and the public grants a monopoly privilege and agrees to accept the service rendered and to pay the cost. If the company's credit is impaired or it fails altogether the community, as well as the company, suffers. It is evident, therefore, that the public should take a keen and intelligent interest in public utility problems, and especially in the situation which has resulted from the rising cost of labor and commodities, for which the companies are not responsible. The government has been rendering important service of this kind, enough to demonstrate its value and to show that cooperation in this work is practicable. But it could render a service of vastly greater importance to the utilities and to the public, by an expenditure say, of one million dollars per year for research and education on utilitiy problems. That would be only one cent per year per capita of the country's population, whereas the value of the service that would be rendered to the public would possibly be fifty or a hundred times the cost.

Standardization of Electrical Batteries

One of the most productive lines of research at the Bureau of Standards recently has been a study of electrical batteries, primary and secondary. They are used in great numbers for starting and lighting automobiles, for tractors and other electric vehicles, for electrical power stations, for telephone exchanges, railway signals, door bells, flashlights and a hundred other purposes. No adequate specifications or methods of test had ever been generally agreed upon when the Bureau took up the work. They were sold without guarantee or adequate statement of performance, and the purchaser had no way of ascertaining just what he was getting. The manufacturers have cooperated cordially and intelligently in the study that has been in progress, and in time it is expected that a complete

set of specifications and methods of tests will be developed. In the meantime the manufacturers have derived important benefit from the investigation and the public is getting a better product. Possibly a hundred million dollars' worth of these batteries are made and sold each year, and if this work could be carried on more adequately and as thoroughly in all lines as it has already been in some lines, it seems a safe statement to make that the public would be benefited not less than five per cent on the entire product. This would amount to five million dollars per year, which is several times the cost of all the work of the Bureau of Standards, and more than a hundred times what the battery work would cost. This kind of research and educational work is like seed that falls on good ground and springs up and bears fruit, some thirty, some sixty and some a hundred fold.

Testing of Government Supplies

For many years electric lamps purchased by the government have been systematically inspected at the factory and samples selected for life test in the laboratory. The information so obtained is utilized in the preparation and periodical revision of standard specifications which are used in the purchase and testing of lamps. Formerly lamps were bought by each department or government establishment separately, without specifications or tests. The prices were relatively high and the quality of the lamps often uncertain or poor. Electric lamps are made by highly specialized technical processes. It is very easy to make lamps that will give light, but difficult to make lamps of high quality. Since government purchases of lamps have been consolidated into large contracts and have been tested according to proper specifications, the prices have been the lowest and the quality of the lamps the highest that the market affords. The ordering of lamps by each department is now a simple routine operation, whereas formerly the separate purchasing of lamps involved dealing with agents of various manufacturers and guessing as to who offered the best values, taking into account prices and such information as was available as to quality. The systematic testing of lamps by the government not only protects the government in its purchases, but it protects the public in large measure, for the testing tends to keep up the quality of the entire product, and so benefits the public. The value of this work, which puts the purchase of lamps by the government on a business basis, and protects the

manufacturer of a high-grade product as well as the user, is many times the cost of the work. The influence of the government, instead of being hurtful as it formerly was, is thus stimulating and helpful to the industry, tending to raise the quality of the product and to improve business methods.

The testing of paper for the government is another example of constructive work which puts the government's purchases on a business basis and tends to help the industry instead of degrade it. Formerly the government bought paper in great quantities on incomplete specifications with inadequate tests. Manufacturers knew that they could supply something different from what was specified, and one who was willing to do so had the advantage over one who supplied what was called for. This was an intolerable situation which was corrected when the specifications were made adequate and tests were complete and systematic.

The value of such work is incomparably greater than its cost, and it would be well if all government purchases were as intelligently and systematically handled as lamps and paper and certain other products now are. It is proposed to establish a central purchasing bureau and to have supplies purchased and delivered in wholesale quantities and tested as to quality, instead of ordering small lots separately that can not be inspected or tested systematically. This would be a long step forward in putting the business of the government on a business basis.

TEXTILES

The textile industry is one of the largest and most important of our industries and one which concerns every man, woman and child in the country. If textiles were standardized, so that they could be bought and sold on adequate and intelligent specifications, and consumers as well as wholesale and retail dealers could know what they are buying and could get what they pay for, it would be of enormous benefit to all. Suppose the brand or name of every textile product was defined in such a way as to convey precise information, and the same name always meant the same quality. And suppose that dyes were tested and certified, and one could depend on the mark as to their permanence, and were told what conditions they would stand or would not stand. Would it not be worth hundreds of millions of dollars every year to the public to have such information? And would it not be a boon to honest dealers, both wholesale and retail? The only class to be in-

jured by such a situation would be those who thrive by misrepresentation or by selling inferior goods on their appearance without representation. It seems almost certain that money intelligently spent in research and education along the lines indicated would yield results of very great value, and while it would involve some expense and trouble, it would be constructive and wealth producing and would raise the standards of business. It seems certain that it would be as useful as the grading of lumber, or cattle, or wheat.

The Chemical Industries

Rubber, leather, paints and the chemical industries generally, include a vast number of products which should be standardized and described in intelligent specifications. In many cases the product can be materially improved with little or no expense, if available information is utilized. Often it is the difficulty in securing information and not reluctance to use it that explains the poor quality. There are great numbers of small manufacturers who would avail themselves if they could of information to improve their product, but who can not afford to engage in expensive research to get the information. The government could supply thousands of small manufacturers with information on hundreds of subjects if an adequate staff were made available to do the work, and this would be of direct benefit to the public which pays the cost. This is cooperative work of the most practical sort, and it has been done already in enough cases to demonstrate how productive of good results it is.

Scientific Instruments

The manufacturing of scientific instruments has recently come to be an important industry in this country. This is partly owing to the greater use than formerly of scientific instruments in the industries, and partly to the war which has largely reduced the importation of scientific apparatus from abroad. An increased protective tariff is proposed to encourage and protect American manufacturers of such apparatus, but if there are no standards of excellence set up and no adequate specifications or guarantees, the purchaser will often be uncertain of what he is getting when he buys such apparatus. The government would do well to cooperate actively with the manufacturers and with scientific and engineering societies in standardizing and describing scientific apparatus,

so that the manufacturer will know better the properties and capabilities of his own output of apparatus, and the purchaser will know how to select apparatus and whether he gets what he orders. In other words, scientific apparatus should be scientifically described and intelligently used, and the government could render an invaluable service in aiding to bring this about. In passing, it may be remarked that the manufacturers of this apparatus will do their part in such work. They are calling for greater service from the Bureau of Standards in instrument testing than it is able to render because of lack of men to do the work.

SAFETY RESEARCH AND THE PREPARATION OF SAFETY CODES

One of the most valuable opportunities for cooperative work by the government is in safety research and education; that is to say, in studying methods of reducing accidents in the industies and in everyday life, in formulating sets of safety rules or codes, and in assisting the state industrial commissions in adopting them and manufacturers in complying with them. More than 3,000,000 industrial accidents occur every year, of which 25,000 are fatal. Many millions of dollars are expended annually by employers for accident compensation, and many millions more are lost by injured employees in wages not compensated. Nearly every state has an accident commission which supervises the collection of compensation for accidents, but many of them do very little to reduce accidents. A few states have provided their commissions with generous sums to enable them to prepare safety rules and put them into effect, and valuable results have been secured by such efforts. Recently a comprehensive program of safety work has been prepared in which many agencies will cooperate. This work includes the preparation of nearly a hundred different safety codes, covering the hazards of manufacturing in many different industries, transportation, mining, and the use of electricity, gas, machinery, and explosives by the general public. These safety codes are more than mere sets of safety rules, often amounting to a standardization of engineering practise in many aspects of an industry, and being of great value in promoting efficiency and good practise as well as safety. They are prepared by the active cooperation of all the interests concerned, including engineering societies, industrial and insurance associations, state accident boards, manufacturers of machinery and appliances, and the federal

government. The work of preparing the codes involves study and discussion, a comparison of experience and a consideration of the best operating methods. Efficiency and good service are considered as prominently as safety. Some of the more important examples of these codes are the Steam Boiler Code of the American Society of Mechanical Engineers, the Electrical Fire Code of the National Fire Protection Association, the National Electrical Safety Code of the Bureau of Standards. A national elevator code, codes for steel mills, blast furnaces, foundries, machine shops, textile mills, saw mills, and dozens of other industrial establishments are being prepared or are under consideration. The government is rendering a valuable service in this work, but the work suffers for lack of funds. The industries, the engineering societies, and the state commissions are doing their share of the work. The government's share is important and should be well done. The cost of the work is trifling in comparison with its value, and it does not seem possible that this work will be allowed to lag or cease for want of funds if the general public could but understand its immense importance and usefulness. Aside from questions of humanity and the economic value of human life, the losses in wages and the damages paid in compensation amount to so many millions annually that the small amounts required for the government's share of the work are significant in comparison. Probably no work of the government is more useful or more productive in proportion to its cost, and none is more needed by the country at large. The states and the industries are waiting to put these safety codes into effect, and the great advantage of national uniformity will result if they are prepared so well that they can come into general use. The work should be strengthened and enlarged at an early day, as a measure of efficiency and economy as well as of humanity and good government.

(*To be concluded*)

THE RÔLE OF INVESTIGATION IN THE MAKING OF A MUNICIPAL UNIVERSITY

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IS investigation of the order of genuine graduate work appropriate in a municipal university? If so, what are its obstacles and its opportunities? Since no American institution of higher education supported mainly by municipal taxation has yet succeeded in building up graduate departments of first rank, these questions must be answered in part by recourse to history, theory, and prophecy.

First traditional practises and beliefs, then realization of their inadequacy, followed by critical reflection—this is a recurring sequence which the history of thought records. Custom precedes analytical inquiry. The background of the leaders of the Greek Enlightenment was a tropical growth of conventional opinions about nature and man. Inconsistencies and conflicts of belief were the source materials of the Sophists and their successors. Plato in particular owes his place in the history of reason to his sustained, daring, and passionate quest for intellectual synthesis. Plato and Aristotle were exponents of the critical and constructive spirit of the higher learning. In turn their teaching became a tradition of the schools.

In America the colleges were founded largely to develop moral attitudes, to perpetuate doctrines, and to advance the corporate interests of religion. That the New England college was a splendid contribution is a position needing no defense. Its intense conviction of the importance of individual and intimate experience with realities is a permanent element in the equipment of the scholar, although the introspective tone of its theology was not congenial with the realism of experimental science. Its realities were spiritual, and the issue of its philosophic temper, broadened and deepened, was not science but speculative idealism perhaps best represented by the late Professor Josiah Royce. So intense in the early days was subjective belief that patience with objective evidences was difficult to attain; the opposition to Agassiz and the long fight in Harvard College to establish the teaching of physics and chemistry are indicative.

The colleges were sectarian, teaching a tradition selected from the rich accumulation of ancient and modern literature. The emphasis on the classics was excellent in order to bring to the student a unitary comprehension of the ancient Greek and Roman world, even if part of the interest in languages was to support a doctrine of mental gymnastics, and to disparage the contribution of the pagan peoples. The sectarian bent brought a principle of narrowness and partiality, opposed to the freedom and scope of the spirit which seeks unity and objectivity of judgment.

In the course of events the colleges of arts no longer confined themselves to the training of those who were expected to carry on traditions, but the weight of the past determined their direction and function. The curriculum was *there* as truth, to be learned and absorbed. Excellent as was its mission, the American college did not and does not incarnate the idea of a university.

Neither do the professional schools give outlet for long-continued brooding, suspended judgment, and critical examination of the postulates upon which technical instruction is based. Both colleges of arts and professional schools teach results primarily. They deal with approved and classic literatures and philosophies, accepted methods and conclusions of science. They enlarge perspective, organize traditions, present theories underlying practises, without reshaping the theories according to the logic of the facts. They afford little time for digging beneath the practise of medicine and law. Assembling under one management a number of colleges of this character does not make a university. Geographical contiguity and legal incorporation are accidents, not essential properties of a university.

Up to this point the considerations which have been advanced in behalf of the currently accepted distinction between the respective ideas underlying colleges and universities would apply to all institutions of higher education, urban or rural, state or privately endowed. A graduate school, or a considerable number of departments dedicated to exploration and synthesis, is a prerequisite to all establishments aspiring to university rank.

There are certain conditions in a municipal institution which bear not so much on the question of theoretical necessity of investigation in order to round out a university, as on practical questions of possibility, hindrances, and opportunities. In this discussion the writer has in mind the municipal university with which he is most familiar. The history of the colleges

now incorporated as the University of Cincinnati has reflected the general movement in America—first a college of liberal arts, then technical and professional schools. It is no secret that in the college of arts here as in other colleges during the formative period the teaching and atmosphere were formal and disciplinary. There were recitations from texts, marks, and strict tutelage alternating with student insurrections. Following a universal trend the college of arts became more liberal in curriculum and government and the professional schools more technical, as the standards of the professions grew more exacting.

In a municipal institution the demand of the community is more direct and compelling than in private colleges. They who pay taxes to maintain a university demand return-values. They expect their sons to be trained in medicine, engineering, and law, their daughters to be fitted for teaching. A municipal university must connect with the insistent needs of the community. It publishes the virtues of cooperation, of application of theory to life, of organic relation between school and institutions outside.

Important results of the demand and the principle follow. Professors in the colleges expend most of their energy in teaching, and as time allows, in keeping up with the literature of their fields. Incidentally some members of the staff must bear the burden of supervisory and administrative duties.

Students are hard pressed to assimilate a mass of technical facts, to gain professional skill, and to "cover the ground" of an arts course. At a period of their lives when generous enthusiasms and powers are waking they are expected to familiarize themselves with a ground which has been traversed by others. Obedience, not initiative, is required.

Commercial standards are likely to pervade the community, hard to reconcile with the specifications of detachment, remote ends, patience, and restraint which are eulogized in all descriptions of the aims of graduate instruction and research.

These consequences, in so far as they relate to the excessive labor of professors and the pressure on students, are not substantially unlike those which face all colleges which grow rapidly in student population and differentiate into schools and colleges, in response to popular demand. The third result, however, the utilitarian temper of the community, although not peculiar to cities, deserves special attention, since at first glance it appears to block all advance in the direction of the higher learning. To the criterion of utility the first reaction of the scholar (whose lot is teaching in a municipal college and whose

past training has been in subjects remote from the hurry and immediacy of application) is definite and more or less violent, according to temperament and rearing. Tax payers are described in uncomplimentary terms, among them being "plebeian," "materialistic," "hard-headed," "and near-sighted." After a time a stage of peace and resignation to the daily tasks of teaching comes on, succeeded by some perception of the citizen's point of view, and, if the teacher is wise, more attention to independent study, even if circumstances are unpropitious. In the University of Cincinnati a graduate school has existed for some years. The output of reviews, articles, books, and degrees has been considerable, and in some departments there now are sufficient laboratory and library facilities, as well as a sufficient teaching staff, to make graduate work worthy of its name. The record has been made in spite of the obstacles noted above, and largely by expenditure of money raised by taxation.

In defense of the attitude of the taxpayers, it must be conceded that the first obligation of a municipal college is the training of undergraduate students for a worthy calling. This has been the historical point of departure and can be justified on grounds of common sense and finance. Now that the printed word has lost its magical potency even in the eyes of the unlearned, the book and all learning are judged by tests of experience. Although the philosopher may inveigh against the test of future consequences in estimating the complete worth of anything, he should not lose sight of the fact that the attitude of the community is consonant with one feature of natural science, whose method is factual, realistic, hypothetical, and pragmatic. Concepts of science represent past, present, and anticipated experience. Especially the scientific departments, pure and applied, have little reason for objecting to their own temper and method when they chance to be used by laymen.

After all, it is not altogether a tragedy for a man to start work under the stimulus and "control" of anticipated eventual use. There is no good reason why productivity and invention may not be furthered by a future reference. There may be something vigorous and sane in the plain man's view. Municipal colleges which aim to develop graduate departments may well stress those phases of advanced work in chemistry, physics, engineering, pathology, bacteriology, and medicine which have some prospect of being useful, the results patent, and symbolic because of their great service. How to combat bacteria, to build bridges, and to decrease the overhead expenses of city administration are intrinsically worth while as problems of

research, and they have the additional instrumental value of leading to general interest in other fields of study in which applications are remote if not impossible. In a municipal institution, therefore, to appoint a considerable proportion of fellows whose investigations will be likely to lead to results which will come home to the community is a justifiable policy. First-rate students will accept fellowships on this basis with more readiness, since successful study in fields of applied science leads easily to positions (other than teaching) carrying decent salaries.

The main consideration, however, is that the approach to a proper valuation of graduate work in a democracy may well be the appreciation by the community of the concrete benefits of research. This stage once reached, there may develop a broader conception of the mutual relation between "pure" and "applied" fields of learning, the community learning to value lines of research which promise no application in our generation. In fact, "applications" have a two-fold relation; they have their basis in generalizations of science which have in part been worked out by thinkers whose intent was merely theoretical, who valued problems for their own sakes. On the other hand, applications often revise abstract concepts and set new problems of a theoretical nature. If the community can be made to see that the continued increase in the conveniences and the safeguards of life depends upon the maintenance of a department devoted to following up problems, it will be ready to support a graduate school.

It may be, too, that a department having the intelligent approval of the community will rest upon a sounder and more lasting foundation than one supported by the gifts of wealthy men, although private bequests are absolutely necessary during the initial stages. However well founded these assertions may turn out to be, a moderate claim is this: since graduate schools should have individuality, one that is backed by the consent and money of the environing municipality will be a significant departure from the older type, the privately endowed graduate school.

A defensible proposition, then, is that the intimate reaction of the municipality upon the college which appears in a demand that the college be of direct benefit to citizens at first may resemble a stone wall, then prove to be an open door, if the instrumental value of higher learning is once demonstrated. A graduate school may be built upon the animus of securing a good basic life for the community and progressively refine the con-

ception of a good life in terms of remote benefit to future generations. In this event there may be a generous support of a relative and functional detachment of the scholar from practical concerns, a state which now in popular apprehension is ground for suspicion and reproach.

First to be stressed is the probational rôle of investigation in the field of the natural sciences in a graduate school which early must meet the objection of ordinary citizens that they will not support a group of dilettanti. There is another almost untracked territory which should be explored, the field of the social sciences. Concepts, methods, and data should be examined and recast. Serious, detailed, and comprehensive studies of social phenomena operating within restricted localities would furnish a body of comparative material which is essential in the formation of sane policy and legislative machinery, municipal and national. In the present state of public nerves this proposal should be made with fear and trembling. Perhaps most people, tough or tender minded, would agree that the absence of well-substantiated principles and methods of orderly adjustment during crises is nothing short of a national disgrace. The unrest, misunderstanding, confusion of issues, and defense of prejudice existing in this post-war period create a situation the gravity of which is fast coming to light. We need thorough statistical investigation and fair interpretation of local crises; studies of the bases of difference and agreement between radical, occupational, and other groups; of deficiencies in institutional organization; of psychological phases of political and economic problems; of the present technique of forming public opinion; of desirable directions of municipal growth. Studies of this character could be summarized and presented clearly and vividly so that the average person would be able to understand. A foundation would then be laid for intelligent judgment and intelligent participation in the concerns of the city and nation. One of the chief defects of our democracy would be removed; namely, the lack of *reliable* machinery for gathering and disseminating facts and bringing home to the citizen their significance. Pious belief in the magic of public opinion is fruitless unless public opinion is well informed and all relevant aspects of problems are open to inspection.

Consistency with the theory of "application to life" leads a municipal university to attack the problems of social causation. It does not follow that now the time is ripe. Until there is a degree of solid support by all classes in the community, until there is sufficient confidence in the integrity and sense of justice

of the investigators, research in this field conducted by a graduate school of a municipal university will have little promise of success. If the results of inquiry run counter to the established order, there will be hostility; if they support the status quo, criticism will come from other quarters. A university which has first been established in popular judgment by constructive and useful contribution in the technical fields, as has been urged, may tell another tale. These are anticipations, however, and may suffer the usual fate of prophecy.

Those who simply assert the problematic character of the venture under present conditions should be distinguished from those who propound another thesis not so self-evident. The claim is that any investigation of social interplay is futile and scientifically absurd, doomed to bankruptcy from the start, because intelligence is not able to penetrate the darkness of societal conflicts, much less to devise concepts and methods which can regulate the conflicting and selfish forces which constitute society.

The problem obviously is methodological, with psychological bearings requiring extended discussion. The questions raised concern the data, methods, and aims of the respective sciences, especially the validity and function of mind in the development of institutions, a central inquiry in the socio-psychological field. These problems are but slightly touched in a few concluding sentences. History seems not only to suggest the crucial place of mental processes in community activities, but also to point out that intellect has scored its greatest success in the study of the inanimate and the simpler life processes. This fact, and the corresponding fact that up to this time drift largely has characterized the sequence of historical events, are not to be taken as proof positive that intellect applied to society is futile either in point of penetration or of organization. For plainly there is *some* understanding of our friends and associates and *some* forecast of events by the statesman. The behavior and purposes of men are guided in school and occupation by tuition and law. Intelligence appears to have a measure of leadership in fields in which it has operated as an approved instrument, and the moral attested by the great war is that ultimately it is safer to base national welfare upon widespread knowledge than on prejudice, custom, and illusion.

But to argue for the possibility of scientific investigation in the field of social interaction, and to contend for a directive function of intelligence in this domain is bootless labor, and does too great honor to the skeptic and the dogmatist. It is a com-

forting memory that reflection on the "politics" of a city, its economics, education, morality, art, and religion was considered a worthy occupation by a Greek disbeliever in democracy whose most comprehensive "monograph" is a searching analysis of municipal activities. The assertion that Plato's conclusions are now discarded in philosophy is no sufficient ground for refusal to undertake further inquiries in which the consummation is not intended to be Utopian social mechanism, but working-hypotheses based on growing experience. It is sound science and sound social policy to give every fact, interest, and group in the community due weight. Perhaps in this decade agencies other than the graduate school will attempt to analyze and evaluate the multiple factors of social situations. A graduate school in a municipality may hesitate to embark upon an uncharted sea. The voyage itself is a necessity and an opportunity, if standards more acceptable than those which vindicate tradition are to affect the actual course of social change.

ABACA (MANILA HEMP): THE FIBER MONOPOLY OF THE PHILIPPINE ISLANDS[1]

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THE variety of plants that yield fibers of greater or less value, in various parts of the world, is very large. Living conditions in the temperate zones are comparatively little modified by these plants, but in the tropical countries they are of enormous importance, being used in countless ways. Thus in the Philippines, plants yielding fiber used for different purposes by the natives include varieties of ferns, pandans, grasses, bamboos, sedges, palms, battans, vines, other plants with leaf or petiole fibers and miscellaneous growths. However, only two Philippine fibers are of notable commercial importance for rope and bag manufacture—abaca and maguey. Minor species that have possibilities of future development and significance in world commerce are the sisal, hennequen, kapok and ramie. Abaca so dwarfs all the others as a Philippine product and is so definitely the monopoly of the Islands that this discussion will deal with it at length, and with the others only as their relative importance warrants. In any event there is so much of similarity in the growth and utilization of these plants that a detailed account of one covers the major points that apply to all of them.

The abaca plant is closely related to the banana and the plantain, resembling them in appearance and habits of growth. The banana plant produces a fiber which lacks the strength of the abaca, and the abaca produces a banana-like fruit filled with large black seeds and economically unimportant. The term Manila hemp usually applied to the abaca fiber is very misleading. Properly speaking hemp is the bast fiber extracted from the inner bark of the *Cannabis sativa.* The so-called Manila hemp is the structural fiber obtained from the leaf sheath of the *Musa textilis.* The term abaca designates both the plant and the fiber under consideration.

Abaca enjoys the distinction of being strictly a Philippine product. As many as fourteen varieties are under cultiva-

[1] The paper is supplemented by one discussing the general regional geography of the Philippines published in the *Bulletin* of the Geographical Society of Philadelphia.

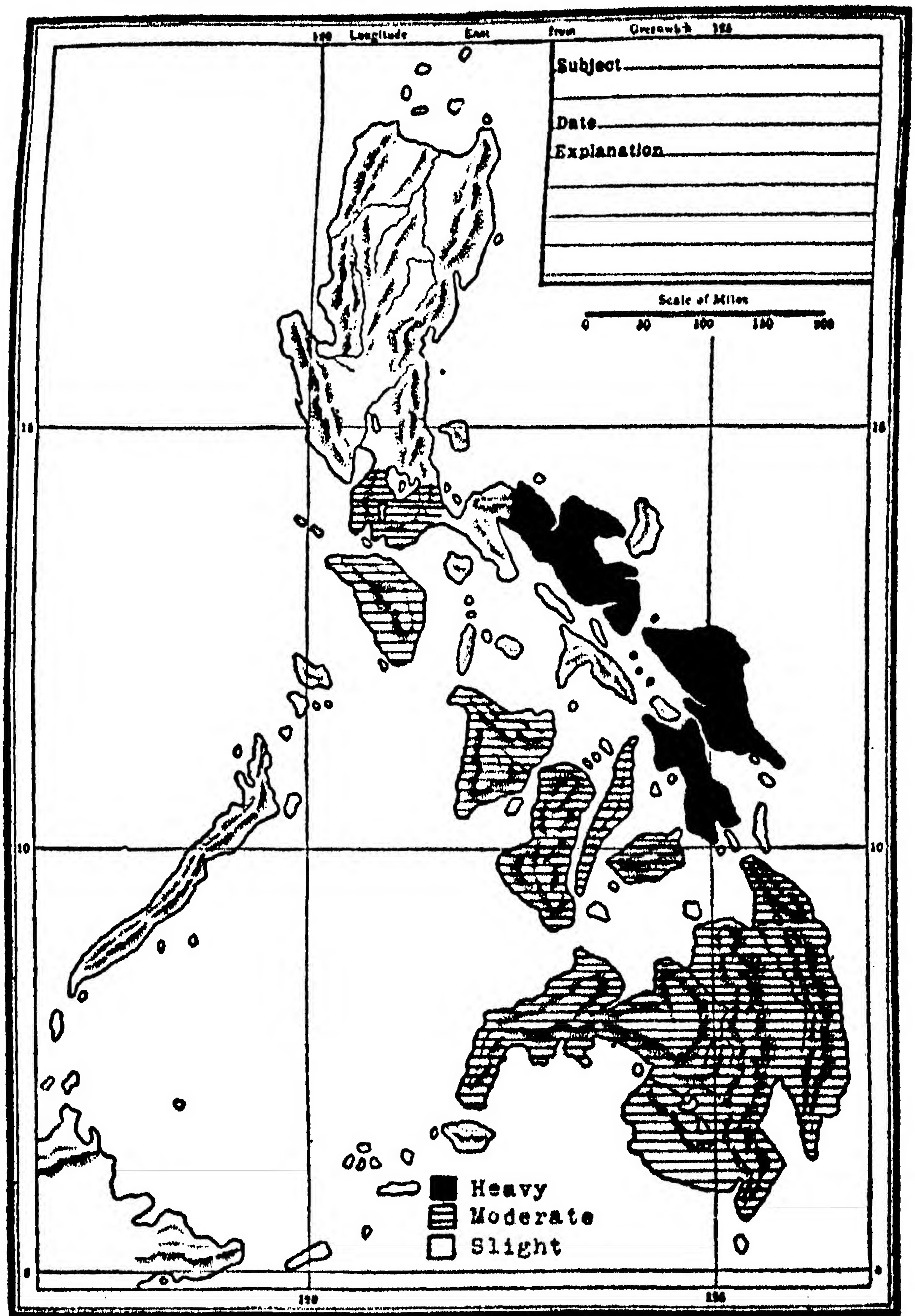


FIG. 1. AREAS OF HEMP PRODUCTION.

tion in the Islands, differing in color and shape of stalk, color and size of leaves, greater or less tendency to produce suckers, and in quality, abundance of strength of fiber produced, and in hardiness. The most desirable qualities are hardiness, rapid growth, ability to withstand drought, and abundant yield of fiber, of good quality and easily extracted.[3]

Abaca is distributed throughout the greater part of the Philippines, but is most successfully cultivated in a district comprising roughly the southern two thirds of the Archipelago. It may be cultivated as high as 3,000 feet above sea level if varieties adapted to the higher altitudes are used.

[3] H. J. Edwards, Philippine Farmers' Bulletin, No. 12, "Abaca," 1910.

The adaptability of any particular soil for the production of the abaca plant depends on the conditions of climate and exposure of a particular location, but if those are favorable it does best on alluvial plains subject to the overflow of rivers and on the moist mellow loams formed by the disintegration of volcanic rock.[3] Dry sandy soils, stiff clays or limestone soils are avoided. Since the bed-rock structure of the Philippines is mainly composed of basic lavas which have been decomposed by weathering generally to notable depths, it will be seen that soil difficulties are not great, and there is ample suitable area for any reasonable development of the industry.[4]

Climate is probably more important than soil in the selection of lands suitable for abaca plantations. The four climatic factors are, rainfall, humidity, winds, and temperature. A heavy and evenly distributed rainfall is most essential unless irrigation water is available. Relatively high humidity is desirable and this nearly always occurs in regions subject to heavy rainfall. The abaca plant is especially unsuited for cultivation in regions swept by heavy winds. Its leaves are heavy and broad and the plant stiff, so that a wind storm may do untold damage. So also are the banana plantations in the West Indies ruined by tropical cyclones. Temperature is relatively unimportant, as it is subject to but slight variations throughout the year in the Philippines and maintains a mean of 75° to 80° F., according to altitudes.

Reproduction of the abaca is usually by suckers, though possible by seed, and the planter may use considerable judgment in selecting varieties high in natural quality and especially adapted to his own conditions. Certain varieties do much better in alluvial soil, while others are more fitted to be planted in loam. The insular agricultural advisers are doing much to spread the doctrine of suitable seed, but before that it was the usual practise to call on the aid of a neighboring successful planter.

In preparing the land, underbrush, weeds, and all trees are removed and burned except those trees necessary for shade or wind protection. There is rarely any plowing or other preparation of the soil. The seeds are planted at regular intervals, and beans, peas, sweet potatoes, or other vegetables are planted in alternate rows as these, by their rapid growth, will choke back the weeds and themselves yield a profitable crop. However,

[3] Edwards, *op. cit. supra*, p. 21.

[4] J. Russell Smith, "Industrial and Commercial Geography," New York, 1913, p. 523.

it is always recommended where animals and implements are available that the planter plow and harrow, and he may be certain of a crop which will yield returns for his extra effort.

Commercial fertilizers have seldom if ever been used in abaca cultivation. Much of the land is virgin and the soil is deep, fertile, and filled with decaying organic matter. Only a very small per cent. of the plant becomes the commercial fiber, the waste parts being scattered on the ground to conserve fertility. A study of the relative value of the various fertilizers has not even been made, but from the composition of the plant and the fiber it is known that potash is by far the most essential requirement.

About the only cultivation necessary is to loosen the soil around the plants and keep the weeds cleared out. This last should be done every two months during the first year. Later when the abaca shades the ground weeding is less necessary, and after three or four years once a season will suffice. Another valuable treatment after the fourth or fifth year is to dig out the decayed roots of old stalks and throw in new soil providing additional plant food.

Shade is desirable, especially where there is any pronounced dry season. The shade prevents evaporation, keeps back the weeds, draws up moisture for the plants and protects them from strong winds. Leguminous trees, with tall trunks, narrow leaves, and deep roots are selected where possible.

The abaca has few enemies, and damage from these is negligible. The larvæ of two insects attack the plant by boring a large hole in the trunk and causing the leaves to turn yellow. Much more destructive are high winds, drought, and the ravages of wild pigs, deer, and carabaos.

The first stalks are ready for harvesting twenty months to three years after planting, depending on locality and variety. After the first harvest it is usual to cut the plantation over every six or eight months. The mature plant consists of a cluster of ten to thirty stalks all growing from one root. The stalk is ready for harvest when the large violet flower bracts fall to the ground.

Harvesting is done by hand with a sharp knife which cuts the stalk a few inches above the crown of the plant. Care is necessary in felling the stalks as an unskilled laborer will allow the stalk to fall to the ground, bringing down other young shoots whose leaves are tangled with the mature stalk. For this reason it is desirable to cut the leaf of the stalk before it is allowed to fall. It is likewise important to cut the stalk on the slant so that water will not stand on the cut and cause rot.

The yield varies greatly, but 1,000 pounds of fiber per acre is considered a good crop. The average probably falls considerably below this.

The trunk or stalk of abaca ranges from 6 to 18 inches in diameter and 2 to 8 meters in length. This trunk consists of a small, central fleshy core from 6 to 10 inches in diameter at the base, to about 2 inches at the top around which a number of thick overlapping sheaths are wrapped, each sheath being the stem of petiole of a leaf. The fiber is extracted from the outer portions of these sheaths. The process of hand extraction consists of two distinct operations; first, the removal of the ribbon-like strips of fibrous material from the leaf sheath, and second, the separation of the individual fibers by pulling these ribbons under a knife.

The laborer inserts under the bark of one of the leaf stems a small sharp piece of bone and pulls off a fibrous strip about 2 inches wide and as long as the stalk. One sheath yields 2 to 4 such strips. Each consecutive sheath is thus stripped down to the central core.

These strips are taken to a shed where the stripping apparatus is kept. This consists of a log set in a horizontal position about 4 feet from the ground. On top of this is fastened a block of smooth hard wood. Over this block is placed a bolo, having a blade a foot long and a handle 15 inches long. A rattan is atached to the end of the knife handle and connected with a bamboo spring above. Another rattan passes to a foot treadle. Thus the spring holds the knife to the block and the treadle regulates the pressure.

In the process of stripping the operator holds a ribbon of fiber in his hand with the end wrapped around a block of wood. He draws it under the knife with a quick steady pull, reverses the ribbon and repeats the process. A small bunch of wet fiber is left in his hands. The work is very exhausting and the laborer can work only part time, and even then is frequently ruptured by the strain of pulling.

The quality of the fiber depends on the condition of the knife blade, the pressure exerted and whether or not serrated knives are used. The latter produce a very poor quality and their use is being discouraged by manufacturer and consumer. Unless closely watched the native labor is apt to reduce the pressure in order to make the pulling easier and this results in poorly stripped fiber.

Beginning shortly after 1900 progress in Philippine fiber production fell off to an alarming degree. The reputation of the industry suffered in the opinion of foreign manufacturers

and dissatisfaction was apparent on all sides. Even more serious was the manner in which fiber plantations were neglected and the quality of the product correspondingly lowered. Defects of organization and lack of control of the industry were felt to be the heart of the difficulty. Before 1914 the grading and inspection, buying and selling of the fiber were haphazard and inefficient. The grading and inspection had been in the hands of a large number of export firms. The grades they established varied continually and tended to increase beyond all need. Market quotations were not well understood and suspicion was aroused in the mind of the seller because of the difficulty of determining whether his fiber had been honestly graded and he had received a fair price for it. Manufacturers and consumers were complaining because the product was not well graded and the general product poorer. The defects in the method of handing the hemp were set forth in the following outline:[5] (1) The lack of fixed and accepted standard grades; (2) the inadequacy of the prevailing methods of grading the fiber and of designating the grades; (3) the lack of any authoritative control over the operation of the grading establishments; and (4) the more or less general ignorance of the producers as to their quality of their product.

To remedy these conditions the Philippine Legislature in 1914 passed a law known as Act No. 2380, "An Act Providing for the Inspection, Grading, and Baling of Abaca (Manila Hemp), Maguey (Cantala), Sisal and Other Fibers." The grading of the abaca was based on color, tensile strength, and cleaning. Four classes were created, excellent, good, fair, and coarse, and each of these was subdivided into a total of twenty-one grades of definite description. The maguey and sisal were divided into two classes, first, fiber cleaned by retting, and, second, fiber cleaned by machinery or with knives.

The fiber grading law embodies the following provisions: (1) The establishment of fixed standard grades for each of the chief commercial fibers exported from the Philippine Islands; (2) the requirement that every grading establishment shall grade and prepare for export in accordance with the established standard and with the regulations; (3) the institution of a system of inspection of all graded fiber, and supervision over all grading and baling operations to enforce compliance with the regulations, and (4) the institution of an educational campaign among the producers for the purpose of improving

[5] M. M. Saleeby, "One Year of the Fiber Grading Law," *Philippine Agricultural Review*, Vol. IX., 1916, p. 13.

the methods of production and preliminary preparation of the fiber.

Under the law 89 grading stations were established and fiber inspectors assigned to the more important stations. Stations without inspectors are required to submit their fiber for inspection on its arrival at Manila or Cebu, the leading ports for export. The law has been so successful in remedying the conditions which it was designed to meet that there are now over 100 stations in operation and a staff of about 50 inspectors.

Uses of Abaca

Abaca is the raw material for a large number of manufactured products. Most of the export trade is with American and English rope factories, and, as they are the dominating market for the fiber, so are they dependent on the Philippines for the source of their supply. Increasing amounts of abaca are being exported to Japan for the manufacture of Lagal hat braid. The growth of this industry is a factor in the large immigration of Japanese to the Philippines. They have settled in Mindanao and Cebu, where the better grades of fiber are grown, and make it their business to see that the Japanese market is supplied with the necessary quantity of high-grade abaca for the manufacture of textiles and braid. The braid is made up in Japan and sent to the United States chiefly where it is used for women's hats. Among a large number of products whose market is local, abaca is consumed in the production of slippers, baskets, bags, matting, lace, furniture, and a coarse cloth.

Possibilities of the Abaca Industry

New uses and new applications of old uses of abaca and allied fibers are being constantly proposed. The extent to which this fiber may be used in the manufacture of paper is significant in view of the present scarcity. The utilization of waste abaca for this purpose was first suggested in 1905. Manufacturers of Manila paper had previously been dependent upon old rope for their raw product. Large shipments of waste abaca began moving toward American paper mills and continued until 1911, when the experiment failed. The reasons stated were that the waste had a relatively low percentage of paper pulp, the quality of the waste was too variable, and freight charges were prohibitive.

Further investigation was made with results stated by the consular service as follows:[6]

[6] Daily Commerce Reports, May 16, 1912, p. 632.

In 1912 twelve large paper manufacturers in eastern United States formed a Philippine corporation to handle and develop the use of abaca and its by-products in the paper industry. The enterprise rests upon the demand for certain classes of paper of an especially strong and tough grade. Experts report that a one inch strip of hemp paper will support 100 lbs. For a number of years there has been a growing demand among manufacturers for the waste products of hemp and old rope to supply this grade of paper, especially as the business of making paper bags for cement, flour, and similar commodities was being extended. The organization backing this industry has spent over half a million dollars in experiments but reports as yet no substitute for hemp. The peculiarity of Manila hemp is that it is practically all fiber in composition, and that no matter how finely the hemp is divided it is still capable of division as fiber, while a fiber of cotton, for example, is only a tiny tube, a fiber of sisal is merely non-fibrous wood, and similar objections are had to other products.

The result has been the conclusion that, all things considered, the use of the whole of the original hemp stalk will be the most economical way out of the situation. By present methods about one third of the ordinary plant is lost in stripping and about one third of the remainder is not used for the reason that the fibers are too small and too weak to be of commercial use. The new plan is to take the entire hemp plant as cut on the plantation and merely crush, dry and clean it in especially designed machinery.

Even at the lower price per pound for the whole plant than he receives per pound for about half of the original plant at the present time, after expensive handling, the planter will actually receive greater returns from his product than by present methods. The enterprise is intended to afford a new and additional supply of raw materials of the sort needed in the manufacture of special varieties of paper—a supply capable of almost indefinite extension.

At the same time the corporation described above organized a company to manufacture paper, cotton and other textile bags of all descriptions. These new industries have prospered and opened the way for further development in a new field.

Another proposition often heard is that there be more manufacturing of cordage in the Philippines and less dependence on foreign manufacturers. The consular service reports this plan as follows:[7]

One of the largest American mail order houses recently endeavored to secure the entire output of Philippine rope. The establishment of an additional factory would not involve the taking of markets away from existing factories. On the contrary a greater supply of Philippine rope would aid the existing factories by establishing Manila as a more important source of supply of cordage. Cebu is believed to be the best site for development of the cordage industry. It has an abundance of cheap labor and is the shipping and transshipping point for a large part of the hemp produced on the island.

[7] *Daily Commerce Reports*, Aug. 16, 1918, p. 634.

Government action to secure this benefit is reported in the following article:[8]

Government officials identified with the organization of the National Development Company, authorized a few months ago by the Philippine legislature, have been gathering data which may lead to the establishment of a rope factory, which will free the Philippine hemp industry from the mercy of the rope factory interests of the United States. Proposals for the organization of such an institution here result from the hemp market depression. Under present conditions hemp men of the Philippines are helpless when rope factories in the States show no disposition to buy the raw material. The National Development Company, which, when finally organized will have a capital stock of $25,000,000, 51 per cent. of which will be government owned, is intended to safeguard Philippine industries when possible, as well as to foster important industries and to offer a helping hand to any industry which has a chance of becoming important, but is not yet developed to the point of being able to walk alone.

Exports of Abaca

The accompanying figures show very clearly the growth of hemp as an export product. It was formerly equal in value to about two thirds of the total exports of the Philippines, but the rapidly developed importance of copra and sugar in international commerce has reduced this figure to about one half. The average prices received for hemp have varied from year to year according to the success of the crop and world market conditions. Since 1914 the war has so influenced the market that the figures stand for little. The total weight of the crop

Hemp Exports[9]

Year	Weight Long Tons	Value (Millions)	Average Price	Per Cent. Total Exports
1899	70,152	8	$113.99	53.8
1900	90,869	13	146.81	57.8
1901	126,245	16	126.55	65.2
1902	113,284	19	170.29	67.3
1903	139,956	22	157.19	67.9
1904	123,583	22	169.48	71.9
1905	130,437	22	166.80	65.
1906	104,078	20	188.44	60.1
1907	117,241	20	167.94	59.5
1908	131,382	17	125.61	50.6
1909	167,953	17	100.60	48.4
1910	163,173	16	100.97	40.6
1911	148,202	14	97.74	32.4
1912	175,137	22	126.05	40.2
1913	119,821	22	176.27	44.2
1914	116,386	19	164.93	39.4
1915	142,010	21	150.27	39.7
1916	137,326	27	194.35	38.1
1917	169,435	47	276.26	48.9

[8] *Transpacific Magazine*, Vol. I., p. 64, 1919.

[9] U. S. Bureau of Customs and Foreign Commerce, "Commerce of the Philippine Islands," 1918, p. 16.

is the clearest indication of steady growth. The bulk of the export trade is with the United States, England, Japan, France, and Switzerland.

Maguey and Sisal

Agave is the family name for a group of important fibrous plants including maguey, sisal, henequen, and zapupe. The first two, only, are of economic importance in the Philippines. While closely related, they have had only a short history in the Philippines and were introduced there from widely separated points. Maguey was introduced from tropical America by the Spaniards, while sisal came from Hawaii in 1905 as a product for experiment. It has been successful, but not to the same degree that maguey has.

The henequen member of the agave family is produced in much larger quantities for world consumption than either maguey or sisal, constituting about 80 per cent. of the world's production of "sisal" fibers as they are known commercially. Maguey and sisal however have points in their favor which should make them of increasing importance compared to henequen, which is grown almost exclusively in Mexico. Their fiber is equally, if not slightly superior to henequen, and their soil and climatic requirements are slight, for they will flourish in rocky limestone soil under conditions of long drought. Their cultivation is simple and inexpensive, not requiring skilled labor, work animals, or agricultural machinery, and they are not seriously attacked by pests.

Reproduction and planting is by suckers and not by seed. The suckers appear (about the second or third year from planting) around the mother plant, springing up from the rhizomes. If to be used in starting new plantations the suckers are set out from two to three yards apart each way, with little preliminary preparation of the soil beyond clearing it of underbrush and weeds. The only attention usually given until the third or fourth year is a periodical weeding out of suckers.

Both maguey and sisal closely resemble our common century plant. The fiber is derived from the essential element of the leaves, but the best and fully developed fiber is found only in leaves from three to four years old, so it is customary to harvest only the two outer rows of leaves from each plant, usually 20 to 30 leaves. The leaf is cut off just above the stem and the spines trimmed to facilitate handling and in this shape they are ready for extraction of the fiber.

The method of extraction commonly employed is "retting," in which the leaves are slit in strips, tied in bundles, and immersed in salt water (tidewater) for 6 or 8 days so that de-

composition takes place sufficiently for the pulp to be scraped off and the fiber left. Retting is being gradually superseded by the machinery invented for the extraction of henequen fiber, especially where the maguey and sisal are grown on a really commercial scale. The machines are composed of a 54-inch wheel revolving inside a heavy wooden or metal case. Across the surface of this wheel are placed blunt brass knives, about eight inches apart. In front of the wheel is adjusted a concave block, or brass shoe, against which the leaves are scraped by the blades of the former.

In 1917 $17,500 was appropriated by the Philippine legislature for the purchase of two Prieto maguey extracting machines in the United States. These were installed at the Singalong experiment station and since that time have given such satisfaction that Hernandez, the Director of Agriculture, believes they will[10] "greatly increase the maguey industry throughout the Philippine Islands and put it on a more stable basis." Some such machinery has long been needed for the extraction of abaca. A number have been tried, but have failed because of low capacity, complexity of construction, and high cost of operation.

After extraction of the fiber it is washed and carefully dried to prevent deterioration. When dry the fiber is tied in bundles four inches in diameter and baled. Subsequent operations are similar to those described in our discussion of hemp.

The sisal fibers are peculiarly immune to disease, two fungous diseases and one insect pest being the only known sources of danger, and these are being carefully watched to prevent any widespread damage. Damage is more likely to occur from cattle when the plantations are not properly fenced in.

The introduction of sisal fibers to the areas of the Philippines offering suitable conditions will result in the use of lands otherwise economically unimportant. The establishment of this industry demands three lines of improvement over the present methods; (1) the practise of systematic planting and cultivation, (2) the development of large plantations, or small ones close together, and (3) the introduction of fiber extracting machinery which will follow naturally after the second condition has been fulfilled.

Growth of Maguey Industry

Production of maguey for export commenced in 1904, when 690 long tons were shipped valued at $78,121. Between 1905 and 1915 the quantity exported varied between 2,000 long

[10] *Philippine Agricultural Review*, Vol. XII., 1919, p. 98.

tons, valued at $163,273 to 7,000 long tons, valued at $590,951, the highest figures being in 1913. In 1916 production rose to 15,686 tons, whose value was $1,746,511.

The future promises much, for experts are entirely agreed that the Philippines offer every opportunity to the new industry. The consular correspondent reports:[11]

> Maguey does well in the islands and there is much land adapted to its culture. The acreage is rapidly increasing.

Maguey is used almost exclusively for binder twine. For this reason exportation is confined in general to the United States and Europe. During the war a specialist in fiber plant production was assigned to the Philippines by the U. S. Department of Agriculture with a view of promoting interest in the binder twine fiber industry. Appropriations were made for experimental and extension work which are now being carried on. In a preliminary report the expert reaffirms the suitability of soil and climatic conditions for increased production of maguey.

Minor Fiber Plants

While this investigator was studying the development of the maguey industry he was authorized to carry on experiments with other fibers whose commercial importance might be developed. These experiments have not proceeded far enough to draw final conclusions but it appears that the kapok fiber will grow satisfactorily. Kapok is the mass of silky fibers investing the seed of the silk-cotton tree. Commercially it is called Java cotton and used as a filling for mattresses.

Attempts have been made to find a type of cotton which may be grown extensively. So far all efforts have failed, but more experiments are being continually tried. The Panama hat plant grows readily and may be grown commercially. Ramie or Chinese grass seems particularly well adapted to conditions. The fiber is of superior quality and is well known in all fiber markets. There is every indication that ramie will be among the fibers exported from the Philippines before many years. The fiber of the pina, pineapple tree, is used locally in making both a coarse gauzy fabric and a very fine textile. Buri raffia is the skin stripped from the leaf segments of the buri shoots before the blade has unfolded. The product is obtained from the buri palm.

[11] *Daily Commerce Reports*, Oct. 30, 1917, p. 411.

THE DIAMOND-BACK TERRAPIN: PAST, PRESENT AND FUTURE

By Dr. ROBERT E. COKER

U. S. BUREAU OF FISHERIES

"BRER terrapin wuz de out'nes' man," Uncle Remus once remarked; "He wuz de out'nes' man er de whole gang. He wuz dat." Uncle Remus, with rare sagacity and dry humor such as never failed him, ascribed to a supposedly lowly animal a unique place among the beings that peopled the world of his fancy. But the terrapin has appealed not alone to the imagination of an unlettered story teller. Among the ancient Hindus, where philosophy or mysticism exercised high reign, the earth has been pictured as a half-sphere borne on the backs of four elephants; and these mighty creatures in turn are shown to be supported upon the back of a single tortoise—not the diamond-back, to be sure, but one of its fairly close relatives. Truly, this suggestion of a tortoise or terrapin as the very foundation upon which the living pillars of the earth find support gives brother hard-shell no mean place in nature's great scheme of things. And even in the present day there exist many persons, neither unlettered nor blinded by ancient tradition, hard-headed business men in fact, that raise the terrapin to lofty rank, rating it, in the unambiguous language of cold dollars and cents, above all other animals which find their way upon the tables where men's bodies are nourished and their palates cajoled.

There is nothing of fancy in the modern exaltation of the diamond-back terrapin, nor would I even seem to suggest that men of to-day, in solemn feast assembled, approach the terrapin in anything of the spirit of philosophy or of performance of religious ceremony. We may be sure indeed that the present preeminent position of the diamond-back terrapin among costly meat foods is based upon sincere gustatory discrimination and that its savory presence is approached with no other sentiments than those which become the highest gastronomic observance. At any rate, it is fairly established that the diamond-back terrapin, lowly as it might seem to the uninitiated, holds no mean place in man's esteem, and we are surely justified in making inquiry into its manner of being, its self-perpetuation, and the conditions of its conservation.

First, there may be those who would know what is a diamond-back terrapin. Well, it is a reptile—startling as that statement may sound to some who would find difficulty in associating the most precious of flesh-pots of America with a class of animals that is generally despised. But turtles (including terrapin and tortoises) form a sort of unique class. They are never like anything else. Persons may dispute whether a certain animal, as a whale for example, is fish or mammal; they may engage in wordy combat concerning the relationships of various sorts of animals; but one can not get up the mildest kind of argument as to whether a particular turtle is a turtle or not. Turtles are unmistakable now, and it seems almost as if they always have been so. We find them in geologic formations dating from Triassic times, and almost as far back as we find them, the same principal groups are recognizable that we have to-day. The missing links that would connect them with other classes of animals are absolutely missing. Perhaps a terrapin did not support the earth originally, or have anything to do with making it, but one was there pretty early any way. Having held its own for such long ages, we may well impute to the turtle clan, biologically speaking, a rare tenacity of purpose, and a signal ability to attend to the essential business affairs of life regardless of the phenomena which, as age succeeded age, have worked marvelous changes upon the face of the earth and the conditions of animal existence. That clan has watched these changes with seeming equanimity. It is little to wonder at, then, that mythologists and fabulists have thought to divine in the tortoise, beneath its taciturn demeanor, inexpressive dome, and inscrutable countenance, a shrewd and super-animal intelligence, or even a sense of cosmic responsibility.

All members of the turtle family are alike in certain essential respects, but they differ widely among themselves in various details of structure and appearance, in habits and in size. There are those of the broad ocean with flippers instead of feet; there are those that live almost continually in the waters of rivers and ponds; there are those that seem equally at home on land or in water; there are those that live exclusively upon land; and there are some that have homes beneath the ground. As to size, there is the great leather turtle or luth of the sea, attaining a weight of half a ton at least; there are the gigantic land tortoises of the Galapagos Islands and of islands of the South Indian Ocean, attaining a standing height of 2 feet; and there are the little mud turtles that we find in pocket-sized editions.

The diamond-back stands at no extreme as regards size, form, appearance or habit; but, among turtles, the diamond-back terrapin is peculiar in one respect; that is in its choice of habitat. There are many species of turtle in interior ponds and streams; there are various kinds of turtles in the sea; but, in the zone between salt and fresh-water, the diamond-back reigns supreme. An occasional sea turtle may wander into the salt creeks; while, from the other side, the common mud turtle, at least, will trespass a little way upon the brackish marshes; but none other than the diamond-back makes its home in the distinctly tidal regions where salt and brackish waters ebb and flow.

Exactly what factors determine the limits of wanderings of the diamond-back are not known. It is exposed to virtually pure sea water in seasons of spring tides, and it has been observed to live with apparent prosperity in fresh water flowing from an artesian well when it has been supplied with sea food; yet it is not known to go into the sea, nor does it ascend coastal streams above the limit of brackish water. On two occasions experiments were conducted in keeping diamond-back terrapin in a pond and a tank of fresh water supplied from the Mississippi River at Fairport, Iowa; but in each case they survived only a few months. At such a place they could not of course receive fresh meat from the sea, and the lack of suitable food may have been at least a contributory cause of death.

Few observations have been made upon the food of terrapin in nature, but such as have been made indicate that they subsist chiefly upon small gastropods, crabs and worms. Feeding is done principally when the tide is up; then, if one is lucky, the terrapin may be found swimming in the marshes and browsing upon the periwinkles that creep upon every blade of grass. So innumerable are periwinkles upon the tidal marshes that there can be no danger of inadequacy of food supply for the small remnant of terrapin that survives in the present day. Indeed, viewing the lavish array of food and the lack of competition from its own kind, there is no occasion for wonder at the great abundance of diamond-back terrapin in former days, when, according to the stories that are told in certain regions, the terrapin were a pest to fishermen whose seines sometimes became choked with them, and when they were the cheapest and most available food to be given the slaves upon the lowland plantations.

Feeding might be continued when the tide is out, but now it seems the instinct for concealment comes more strongly into

play and the terrapin crawl into the mud where they may be partially or entirely concealed. I have known a terrapin to submerge itself in soft mud deep beneath a blue crab which had previous possession of a small bare spot amidst the marsh grass. Its presence there could never have been suspected but that the observer was close on the trail.

Needless to say, with animals now so rare and possessing so well developed an instinct for concealment, the fisherman or collector who would find them must needs have keen vision or else shrewd knowledge of the habits of his prey. Skirting the small open places in the marsh, or following the shores of a proper creek, and inserting a stick into the mud at suspicious places here and there, may be the means of acquiring an occasional prize. However, the majority of the diamond-back terrapin brought to market are taken more or less by chance by fishermen pursuing other manner of prey.

When winter falls, the diamond-back, like other terrapin, ceases from its labors, finds shelter in the mud, usually, no doubt, in the deeper places, and remains comparatively dormant. Rarely in midwinter the hibernating terrapin is grappled by an oysterman working over a mud bottom; but it is said, too, even in the same season to be taken occasionally upon the high marshes. Little, if any, study has been made of the behavior of terrapin in hibernation. When they have been retained in an enclosure offering essentially natural conditions, I have observed that while hibernating they did not remain always in one spot. Occasionally an individual has been observed to creep slowly beneath the mud, or even to rise and swim at the surface. In this pen, none would come for food after hibernation had begun; but in another and smaller enclosure, supplied with water of nearly constant temperature from an artesian well, terrapin, on any warm day in winter, would come out in numbers to sun themselves upon the sand, and at such times they would take food as eagerly as in summer.[1] It has since been found that young terrapin kept and fed in a heated wintering house will make rapid growth during the first winter. Terrapin can withstand for a short time, at least, cold severe enough to leave them encased in ice.

Little is known of their enemies and doubtless the large terrapin have few, but the young must not infrequently fall a prey to fish and birds and to rats and other mammals.

[1] Coker, R. E., The Natural History and Cultivation of the Diamond-back Terrapin. Bull. No. 14. The North Carolina Geological Survey. 69 pp. Raleigh, 1906.

In regard to propagation, be it said first that the diamond-back terrapin practices polygamy, or, more correctly perhaps, indiscriminate mating. Experiments indicate that a ratio of about one male to three females in a pen is sufficient to insure a maximum of productivity in fertile eggs and healthy offspring. It is perhaps only a coincidence that, in every brood that has been reared in the Bureau's experimental work, females have far exceeded the males in number, one male to three females being a high ratio. It is not yet known whether or not this difference is due to the loss of males by death before the terrapin attain an age at which the sexes are externally distinguishable. There is another curious characteristic of terrapin. Mating does not have to occur each year. Females entirely separated from males after having mated will continue to lay fertile eggs for three of four years, but after a number of years the eggs produced are infertile and mating is again necessary before eggs will be laid from which young terrapin will develop.

Egg laying in the region of Beaufort, N. C., occurs principally in June and July though it may sometimes begin earlier. At this time, at least, the female terrapin must come out of the tide-washed regions of the marsh and tread upon dry ground. Here and there amidst the marshes the winds and waves have built low sandy hummocks upon which the terrapin often finds conditions suitable for the incubation of its eggs. In such a location I have found several nests, each containing from two to eight eggs buried beneath six or eight inches of sand. It has been observed in experimental breeding pens that some terrapin will lay more than once in a season. Professor Hay has described the process of nest making.[3] The female terrapin, having selected a suitable location, if available, scoops out with her hind feet a jug-shaped hole about 5 inches deep and 2½ or 3½ inches in diameter at the widest part. This is the "nest" into which she backs as far as possible and drops her eggs; then, having carefully replaced the sand or earth and packed it down, she conceals the spot by crawling back and forth over it, and goes away to leave the eggs to their fate. If the sand bed is too dry and another suitable nesting place can not be found, she drops her eggs wherever she happens to be. Usually a single nest contains but eight or nine eggs, but the average number of eggs laid by a single well-grown female is known to be much higher.

[3] Hay, W. P., Artificial Propagation of the Diamond-back Terrapin. U. S. Bureau of Fisheries Economic Circular No. 5, Revised, pp. 1–21. Washington, 1917.

That is all that we can say of the relation of the diamond-back terrapin to its family. Mating occurs at a seasonable time; eggs are laid in a proper place, and sometimes in an improper place; and, so far as we know, neither parent ever gives thought to the welfare of its offspring or even recognizes them when they meet in passing.

The young hatch from the eggs after eight or nine weeks and may remain in the nest for some time, perhaps all winter. Most of them, however, soon emerge from the nests, but only to find prompt concealment in the sand or mud or under grass and drift. Moreover the young terrapin in nature seem to take no food before the following spring and it is only then that growth may begin.

The evidence from the study of the rings on the scutes of the shell indicates that terrapin grow at a variable rate, and that a good rate of growth is about an inch or a little less a year (measured on the bottom shell) during each of the first two years, somewhat less during the third year, and about half an inch for each of the next two years. Sometimes growth is more rapid, for terrapin have been found 5½ inches in length and bearing evidence of not exceeding five years of growth; more often, as it seems, growth is somewhat slower.

The sexes become distinguishable in the third or fourth year when the females have attained a length of 3¼ to 4 inches and the males a length of 3 to 3½ inches. When growth is accelerated by winter feeding of the young in confinement, sex differences, according to Hay, become evident, during the third summer. The conspicuous external differences between the sexes are the much larger proximal section of the tail and the smaller head of the male, with usually a more wedge-shaped rear outline of the carapace. The females, too, are deeper-bodied than the males. It can be observed now that the males are falling behind in rate of growth. They are, in fact, nearing full size when the females are but midway of their physical development. The average size of adult males is about 4 inches on the bottom shell; the largest example I have measured had a plastron length on the middle line of 4.16 inches, though a dealer told me that he had once possessed a 5-inch male. Females, on the other hand, normally attain a length of 6 inches or more, applying the same standard of measurement. A length of 7 inches is not infrequent and, at different times, each of two dealers has stated that he once sold a dozen measuring over 8 inches. One of these men assured me that he had had a female measuring 9¼ inches. Such a terrapin would probably

have measured 18 inches from end of snout to tip of tail—a giant indeed among diamond-backs. It is apparent that the valuable terrapin of commerce is the female. The males are sold, however, and in many instances no doubt the undersized females go along with them. They are quoted as "bulls," formerly at $10.00 to $12.00 a dozen, while "half counts," or females measuring between 5 and 6 inches, would bring twice as much, and "counts," or those measuring 6 inches or better, would command $36.00 to $40.00 or more; 7-inch terrapin, which are not rare, could be sold at $60.00 to $70.00 per dozen. The two exceptional dozens of terrapin measuring over 8 inches, previously mentioned, brought, according to the dealers, in one instance $96.00 and in the other $125. These are all wholesale prices, the retail prices being, of course, substantially higher.

Viewing the delay of wild terrapin in starting to grow, and the relatively slow growth, particularly during the later years, and, in connection with these facts, the great increase in commercial value with growth in size, it is evident that marked economic benefits may be derived if growth can be accelerated by the application of cultural methods and selection.

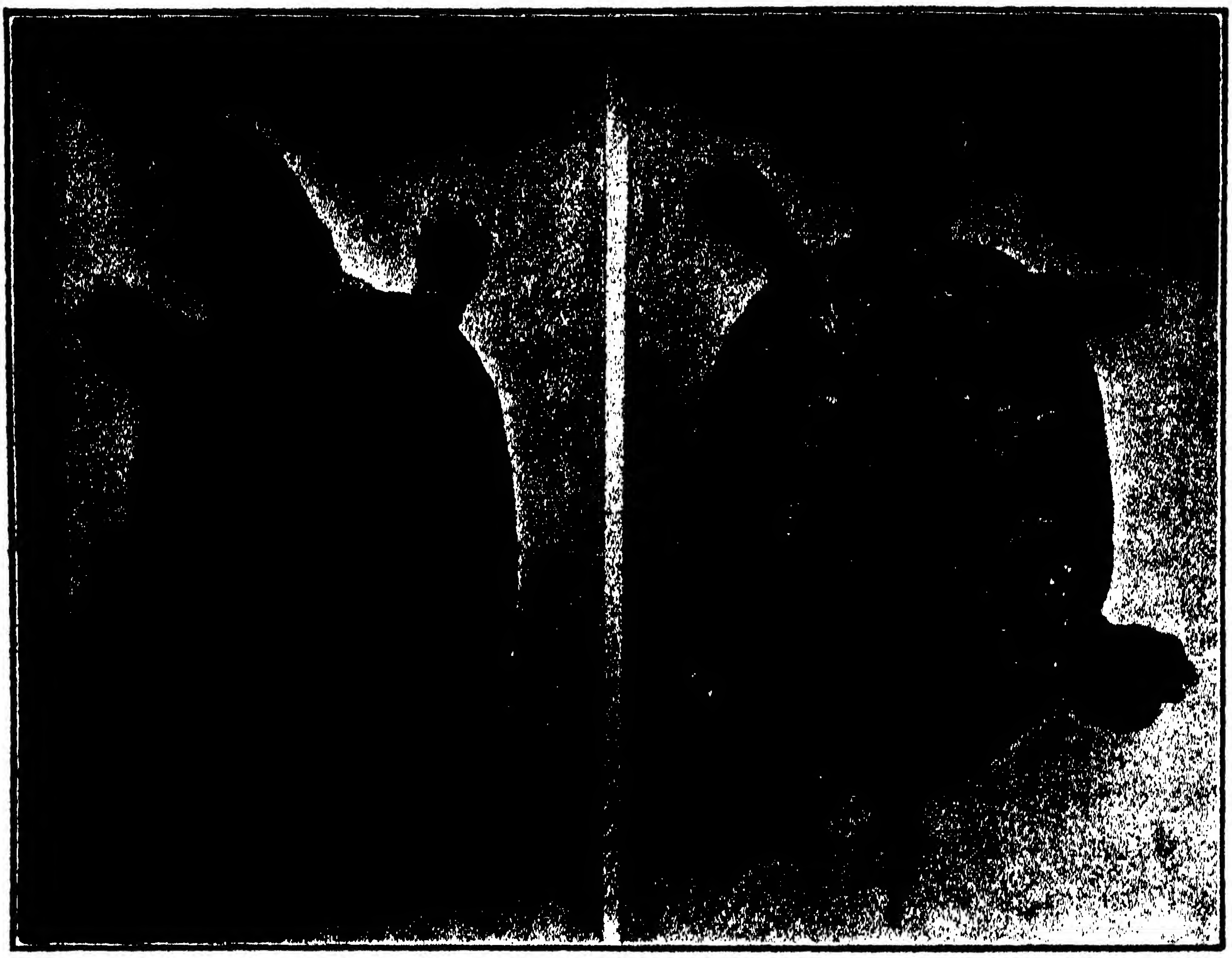
It is fair to presume that there is opportunity for selection. Certainly there is great diversity among terrapin in nearly every characteristic. The variation, or, one might say, the individuality of diamond-back terrapin, has attracted frequent comment from observers (Agassiz, Bangs, Hay and Coker).[3] In size, in color, in depth, in outline, in smoothness or roughness of shell, scarcely any two are alike. In behavior too—in activity, boldness, promptness to take food and other respects—distinct individuality is manifest among terrapin in confinement. Correlated no doubt with activity and aggressiveness in feeding, pronounced differences in rate of growth are indicated by the rings on the scutes of terrapin of different sizes in nature, and conspicuous diversity in size marks terrapin of the same age when reared in confinement. If such traits or characteristics as those upon which differences in rate of growth are based are hereditary, and one might suppose they were, there is reason to

[3] Agassiz, Louis, Contributions to the Natural History of the United States of America. Vol. 1, Part 2, North American Testudinata. Boston, 1857.

Bangs, Outram, An Important Addition to the Fauna of Massachusetts, Proceedings of the Boston Society of Natural History, 27, Boston, 1896.

Coker, *loc. cit.*

Hay, W. P., A Revision of *Malaclemmys*, a Genus of Turtles. Bulletin U. S. Bureau of Fisheries for 1904, Vol. XXIV.



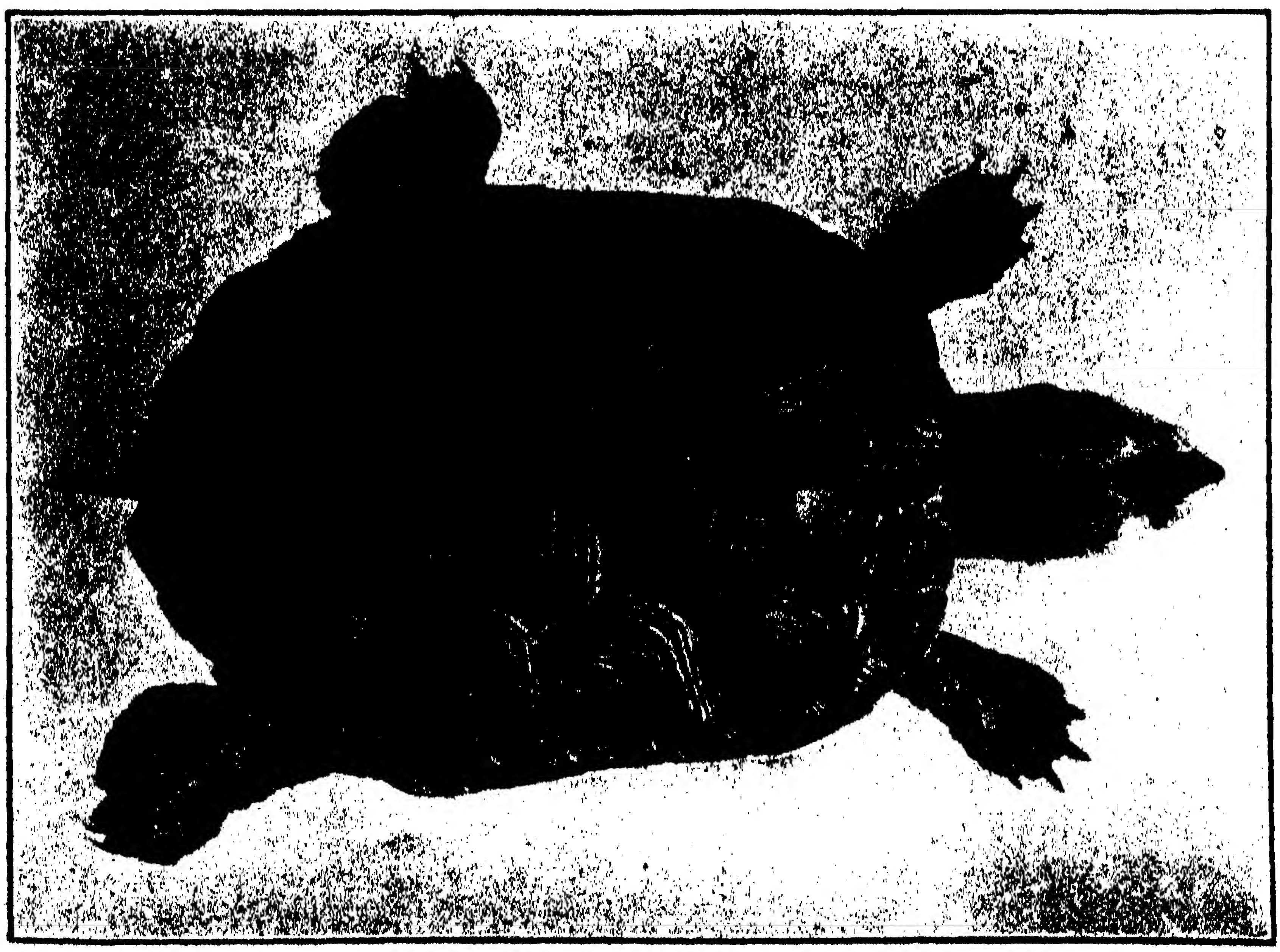
THE FEMALE OR "HEN" TERRAPIN has a much larger head and a smaller tail than the male or "bull." They also attain a much greater size. The relative sizes are not indicated in this illustration except as suggested by the 3-inch rule shown at the right of each example. The length of the bottom shell of the female was 6.5 inches, of the male 4.1. total lengths, 10.87 and 7.5 inches, respectively.

believe that by proper selection a more rapid growing race of terrapin might shortly be developed.

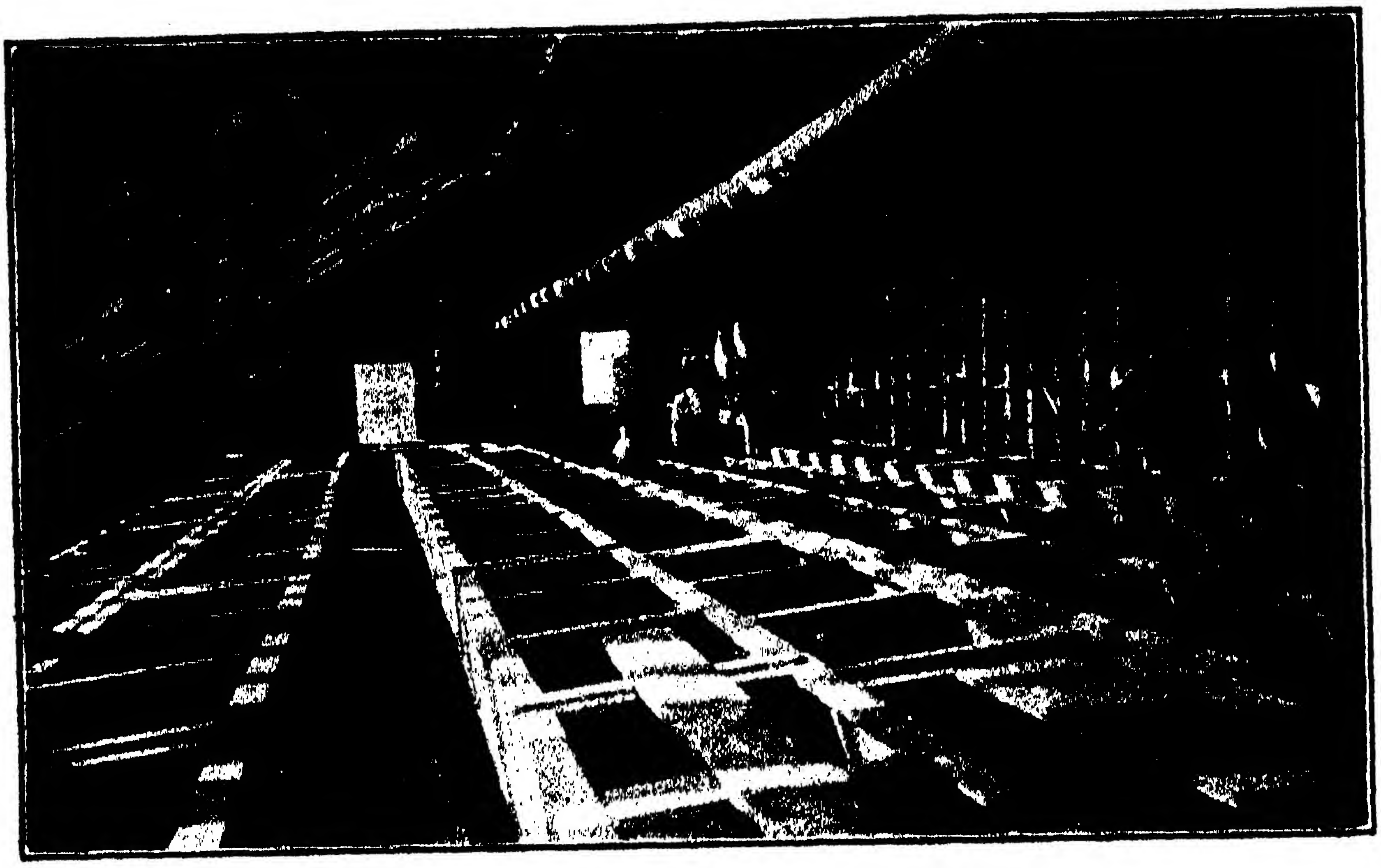
But there is another chance of accelerating growth, and that is by eliminating the waste periods of winter, especially that first winter which normally is passed before feeding and increase in size are begun. This suggestion was originally offered by Mr. H. B. Aller in 1911 while Superintendent of the United States Fisheries Biological Laboratory at Beaufort, North Carolina. My experiments (p. 174 above) had already shown that terrapin will feed during the winter when given favorable conditions of temperature. Mr. Aller's significant suggestion was given effect when there was constructed a wintering house in which terrapin of various ages were kept and fed during the cold months. The house was built much upon the plan of a greenhouse for flowers, having a long sloping glass roof with southern exposure so that the heat of the sun might be availed of to the fullest extent; in addition, a small stove was placed in the center. The effort was made to maintain a temperature of about 80° F.

The results of this experiment abundantly justified the suggestion, at least as regards the stimulation of growth during the first winter of life. By the beginning of the following summer, at a time when, if left to themselves and the usual course of hibernation, the young terrapin would have been approximately the same size as when hatched from the eggs, or slightly smaller, many of the winter-fed terrapin had attained a size normally characteristic of terrapin two or three years of age. As regards growth secured during subsequent winters, it was determined, after experiment, that the increase in size of older terrapin while notable, was scarcely sufficient to justify the expense of feeding the larger terrapin with their correspondingly greater individual food requirement.

These considerations lead us naturally to the subject of the culture of the diamond-back terrapin, a field in which experiments have been conducted by the Bureau of Fisheries for nearly twenty years. The results of these experiments, as realized up to a comparatively recent date, have been epitomized by Dr. Hay in an Economic Circular of the Bureau of Fisheries entitled "Artificial Propagation of the Diamond-back Terrapin." Having referred the reader to that publication, I may be very brief in outlining some of the conditions and practices of terrapin culture.



GOOD ENOUGH TO EAT though only half-grown.
A female diamond-back. Plastral length 4.44 inches.



More than 25,000 newly hatched terrapin were kept warm and fed through the cold season in this winter house of a commercial terrapin farm at Beaufort, N. C.

The first requirement is an enclosure, or several enclosures, of considerable size, in which the adult terrapin can live and feed and grow. In such an enclosure, or pound, the terrapin should find, as far as practicable, the same variety of natural conditions which he encounters in the wild state. There should be water of fair depth with soft mud bottom for hibernation, marsh, dry ground and a laying bed of fairly clean sand above the level of high tides but not so far above the water level as to be unnaturally dry. It is thought that the space enclosed should be of such an area as to allow about 10 square feet for each adult terrapin.

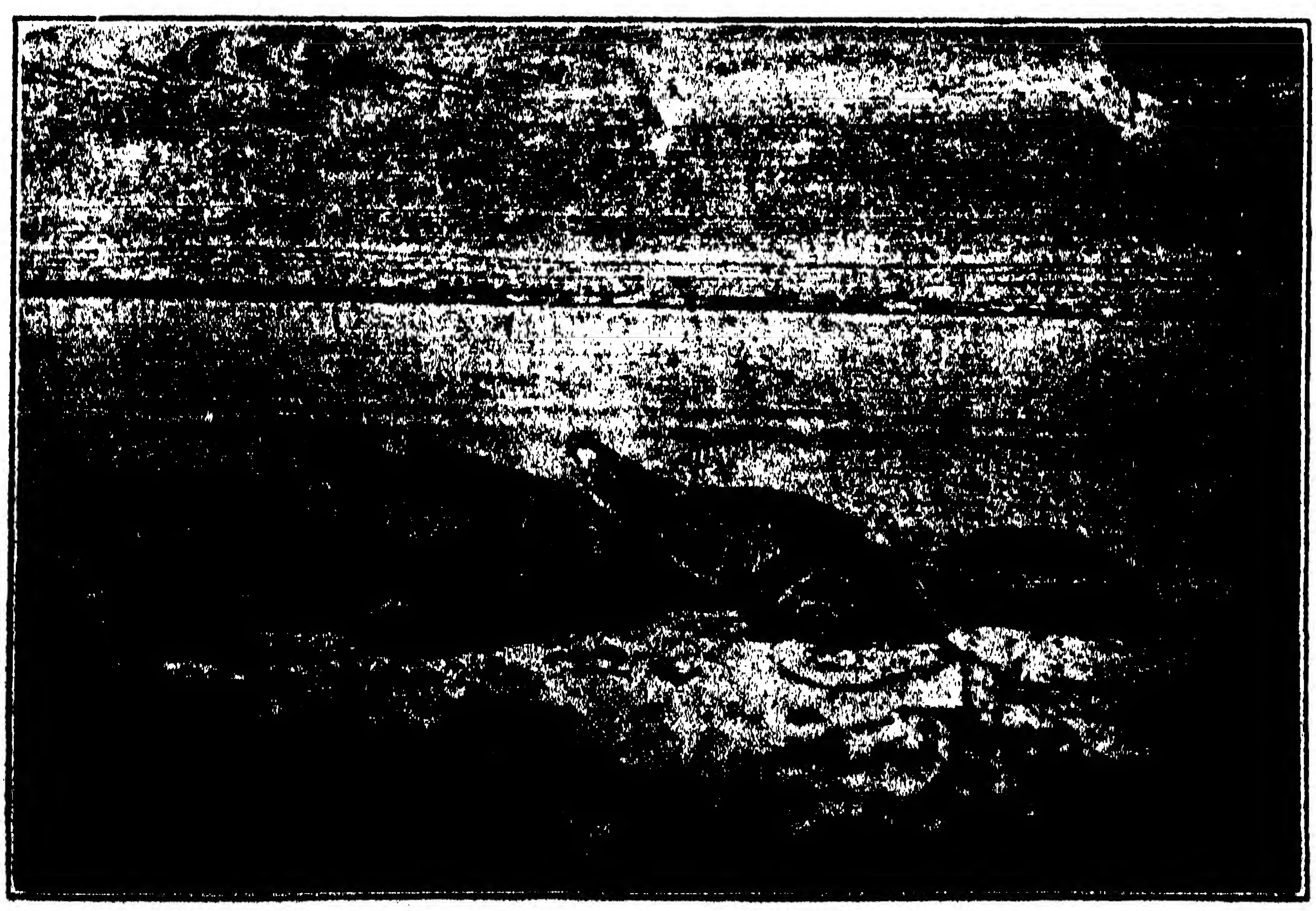
The second requirement covers separate enclosures for the young terrapin of different ages. Diamond-back are not known to be cannibalistic; in fact, the entire indifference of the adult terrapin to the young is the principal occasion for trouble, for the young terrapin are likely to be trampled by the large ones. The growing terrapin also have a better chance to feed if segregated according to size or age.

A third requirement for most effective results is the winter house such as has been previously described. This must have its proper equipment of water, tanks, and small troughs or trays in which the young terrapin are kept and fed. There must also be a home for the watchman and due provision for protection of the valuable stock by means of proper fencing. It is not known that fresh-water is absolutely essential to diamond-back terrapin but a supply of running water is very desirable in connec-

tion with a terrapin farm for use in cleansing the feeding boards or troughs. Not less essential than these physical requirements are the availability of a proper food supply and, finally, wise and attentive personal supervision.

The staple article fed to the terrapin at Beaufort is fish, but an occasional feeding of blue crabs or fiddlers is given. During the winter the young terrapin are fed as far as possible upon oysters, using those of the "raccoon" type which appear abundantly in shallow waters about Beaufort and which can be obtained at a low price. The fish used are obtained from local fish houses or direct from fishermen, those being employed which are not valued on the food market because of kind or size. The food must be cut into small pieces before being fed to the terrapin, and this can be done either with a hatchet and board or by the use of a common meat grinder. Quantities amounting to about 2 ounces for each adult are supplied every day during the season of activity, or from April 1 to December 1. In 1917 it was estimated that the daily cost of food ranged from five to ten cents per one hundred animals.

It is interesting to observe how quickly terrapin will learn to associate certain signs with the occurrence of meal time. If the meat is regularly chopped on a board before they are fed, within a few days the sound of chopping or rapping will be sufficient to bring large numbers of terrapin out of conceal-



HALF-GROWN TERRAPIN, "TAKING THE SUN."

ment and cause them to assemble at the feeding place. At one time I fed some terrapin at night for a short period. After but a few days, the bringing of a light to the pen in the evening was sufficient to bring the terrapin out in force.

Cleanliness is an essential condition of success. In the winter house proper sanitation requires the thorough cleaning of the terrapin boxes every day and preferably the rinsing of each box with a suitable antiseptic solution. As regards the larger pens, sanitation may be accomplished chiefly by natural means, that is, by having a sufficient tidal flow of brackish water through the pen and by the avoidance of overcrowding. Diamond-back terrapin seem little liable to disease, but they can not withstand highly unfavorable conditions, and, where terrapin are greatly overcrowded, or filth is allowed to accumulate in the pens, or other conditions are distinctly unnatural, most serious conditions of disease have been known to develop.

The results of the experiments may be summarized. It has been shown, that terrapin born and reared in confinement develop in a normal way and will reproduce their kind; that the reproductive cycle may be completed in 6 or 7 years, when the terrapin hibernate in nature; and that, by preventing hibernation and forcing growth through the first winter by feeding in a heated house, the maturity as well as the growth of the terrapin may be advanced by one year, so that a new generation is started in 5 or 6 years rather than in 6 or 7.

The adult breeding stock of terrapin steadily increased in productivity from year to year until a certain maximum was reached. This is well shown by a series of figures showing the average numbers of young produced by the females of the original breeding stock during a series of years. In 1912, for example, the pen of breeders containing the oldest stock yielded 12.81 young per female. The yield rose each year until 1915 when 21.43 young per female were taken. Later years brought somewhat smaller crops, but never less than that of any year preceding 1915. In 1919, the number of offspring per female exceeded 19. Some of these breeders have been in captivity about 17 years.. Experience, then, indicates the advisability of retaining a select brood stock for a rather indefinite period, instead of adopting new breeders from year to year, as might be done in stock raising.

The value of winter feeding during the first season is well established by the increased rate of growth, the shortening of the time required to attain reproductive maturity, and the very low rate of mortality. The death rate is generally low. Among

700 newly hatched terrapin fed on fresh food one winter the loss was about 6½ per cent. The death rate in hibernating stock was 13 per cent. According to computations made about three years ago the cost of food for winter feeding at Beaufort varied from 3 to 15 cents per 1,000 young terrapin per day, according as salt fish, fresh fish, or oysters were used. Assuming 10 cents as an average daily expenditure per 1,000 terrapin, the cost of food for 1 terrapin for a period of 5 months in the first winter was, at that time, 1½ cents.

The death rate among terrapin after the first season is so small as to be nearly negligible. It is found to be about 1 per cent. in the second year, diminishing with age to one half per cent. and less. The principal mortality occurs in the first season, and is then chiefly among the "runts," which should properly be culled out in ordinary practise. The losses are remarkably low when it is considered that deaths occur principally when terrapin are very young and before they have become a source of expense, and that the productivity of the terrapin is such that even a loss of 30 per cent. at this stage could readily be compensated for by increasing the numbers hatched and saved for rearing. So far as regards disease and death rates, the rearing of terrapin is a matter of much less difficulty than the raising of poultry.

The history of the experiments during many years gives strong grounds for belief that domestication of terrapin is accompanied by increasing productivity and diminishing disease and mortality.

The experiments in terrapin culture have not the nature of small laboratory tests but are carried out upon such a scale as to be comparable to commercial operations. There are usually about 3,000 terrapin under observation and classified in 20 or more experiments which are being directed to obtain definite answers to several practical questions that yet demand attention and justify the continuance of the investigations. It has been possible also to check results against those obtained in a commercial farm which adopted methods based upon those followed in the Bureau's work. From this it appears that the various results gained in the Bureau's experimental work are not to be taken as exceptional, but that they are, in a general way, typical of what may be expected in cultural operations conducted according to sound principles and with the exercise of proper care.

Now let us consider briefly the past, present and possible future economic history of the terrapin. Diamond-back ter-

rapin occur along the Atlantic and Gulf coasts of the United States from Buzzards Bay, Mass., south and west to Texas. At one time it was considered that there was but one species; but, after comparison of specimens from many regions, it has been determined that the terrapin should be classified in 4 species and one subspecies.[4] They may be called geographic species; one replaces the other as we pass from one section of the coast to another. The several species, no doubt, represent adaptations of essentially the same form to different climatic conditions. It is commonly known among market men that the quality of terrapin varies according to the geographic region from which they are derived. It seems that in the earliest days of terrapin glory the Delaware Bay terrapin had highest rank; owing partly, no doubt, to the depletion of Delaware terrapin, the Chesapeake Bay came to be depended upon for the market supply and for many years now "Chesapeakes" have held unrivalled rank. As the diamond-back became scarcer in both of these bays, some shippers of Chesapeake terrapin began to replenish their stock with terrapin brought from North Carolina waters. After these had been kept for a short time in pounds on the Chesapeake Bay they were sometimes mixed with native terrapin and shipped to the markets as Chesapeakes; others, no doubt, were sold correctly as North Carolina terrapin. It is certain, too, that some South Carolina terrapin were brought into North Carolina to be shipped with those of the latter State to the Chesapeake and thence to city markets. Thus many terrapin of comparatively low value, gradually acquired social prestige, as it were, by a course of travel from point to point along the Atlantic coast—from Georgetown, S. C., to Wilmington, N. C., from Wilmington to Beaufort, from Beaufort to Chrisfield, Md., and finally from Crisfield to Baltimore or Philadelphia. Had these terrapin carried hand-bags, they might have displayed an array of hotel stickers to shame the traveler returned from Europe. Even some terrapin from the Gulf States seem to have reached the markets of Baltimore and New York by a devious journey through the hands of dealers in Virginia and Maryland. It is understood among market men and others that the farther south and west the point of origin of the terrapin, the lower their quality. For many years, however, there has been evidenced an increasing willingness of consumers to accept at a lower price the terrapin from southern waters and this has served to check the otherwise unlimited rise in the price of "Chesapeake" terrapin.

[4] Hay, W. P., 1904, *loc. cit.*

We have seen that the diamond-back terrapin has had a somewhat varied economic history, although development in the past has been in one direction. In colonial days it was the cheapest of foods, constituting a diet for slaves which became so monotonous as even to cause, it is said, an eighteenth-century strike for better food. By the early twentieth century it was the rarest of delicacies in meats. This brings us to the present, or at least nearly thereto. The war has recently intervened, with its stimulation of thrift and frugality in food, to give the terrapin a slight commercial setback. From this it has not fully recovered, and, regarding the recovery, there is a certain problem; it may be that there are two problems.

In the first place, it is well known that in times past, barely past indeed, a self-respecting chef would never give a dish of terrapin license to appear in public unless it had received its baptism of sherry. Anything else was impossible, they said. The laws of the Medes and Persians were not more strict than this dictum of chefdom. New times call for new rules; but the question is, will the terrapin survive the present regulations? Now it might be said by some that the terrapin will pass with the wine cup; that the extreme savoriness of the dish arose from the vineyard where the juice was pressed from luscious grapes rather than from the briny marshes where the particular terrapin had its former being. There is much to say against this. If the savoriness of the favored dish was due primarily to the wine that had been added, why did intelligent and experienced persons pay fancy prices for diamond-back terrapin, when other kinds of meats, other species of terrapin, too, were always obtainable at far less cost? It is known that fraudulent "terrapin" stews for the inexperienced were made from fresh-water terrapin, from chicken, and even from veal, but the evidence all indicates that the wise in the mysteries of gastronomy were never deceived by such imitations. Truly, the diamond-back terrapin must have an inherent flavor that is held to justify the price at which it is purchased. Assuming this to be the case, it is not at all improbable that, as the connoisseurs in foods adjust themselves to the new conditions when wine is no longer a condiment for any pot of flesh, the diamond-back terrapin will continue to hold its relative rank among the favored viands. The future will tell.

One other fear, apart from the effect of the ban upon "spiritual" condiments, has been voiced by a terrapin dealer. "They are dying off," he said, meaning good buyers; "It is the old buyers only that come to me for diamond-backs." This

introduces the question of the future of epicureanism in America, a question not altogether extraneous to our present subject of discussion. Are the epicures of to-day relicts of a past generation as some have suggested? While personally, I am not of the epicures, yet I have no lack of faith in the usefulness of the clan. I am not an athlete and am conscious of no desire to become one, but if I should be told that the athletes are dying off and that those which remain have acquired their skill in a past generation—I should probably "view with alarm" the impending physical deterioration of our race. Just what is the public service of an athlete it may be hard to say with entire correctness, but I have a feeling that, with their high bodily and mental skill and endurance, they are pathfinders in physical achievement, examples of possible accomplishment and leaders or stimulators of normal, healthy physical development. Just so, the epicure with his highly developed organs of taste, keen discrimination and balanced judgment in matters gustatory, discovers the possibilities in the selection and blending of foods and condiments, blazes the way to perfection of appeal to the palate and indirectly, it may well be, leads to the betterment of general standards of cooking. Physiologists tell us that savoriness of food has a decided effect upon efficiency of digestion and effectiveness of nutrition. Penologists assure us that bodily nourishment, or the lack of it, has much to do with disposition to crime. Is it possible that the epicure is one of the corner stones of human morality? At any rate I trust that his kind is not to be extinguished.

It is not meant to suggest that the fate of the terrapin, dietetically speaking, is contingent upon the survival of the epicure, as that term is understood. As regards the commercial future of the diamond-back, it would, indeed, be a sad commentary upon the fallibility of man's honored organ of taste if, after it had extolled the terrapin for so many years, it should now proclaim that the diamond-back of itself is not more savory than anything else. We shall adjust ourselves to revolutionary changes, we shall submit to the subversion of many cherished standards of thought and practise, but we shall not willingly sink to that depth of pessimism which anticipates that the supreme court of gastronomy will reverse itself. The terrapin had its course of training; it passed the high tests imposed upon it; it received its diploma and order of merit. Shall it not meet a changing world, and even go forth from cloistered epicurean walls to win and hold a broad esteem? The Diamond-back forever!

THE PROGRESS OF SCIENCE

WILLIAM CRAWFORD GORGAS

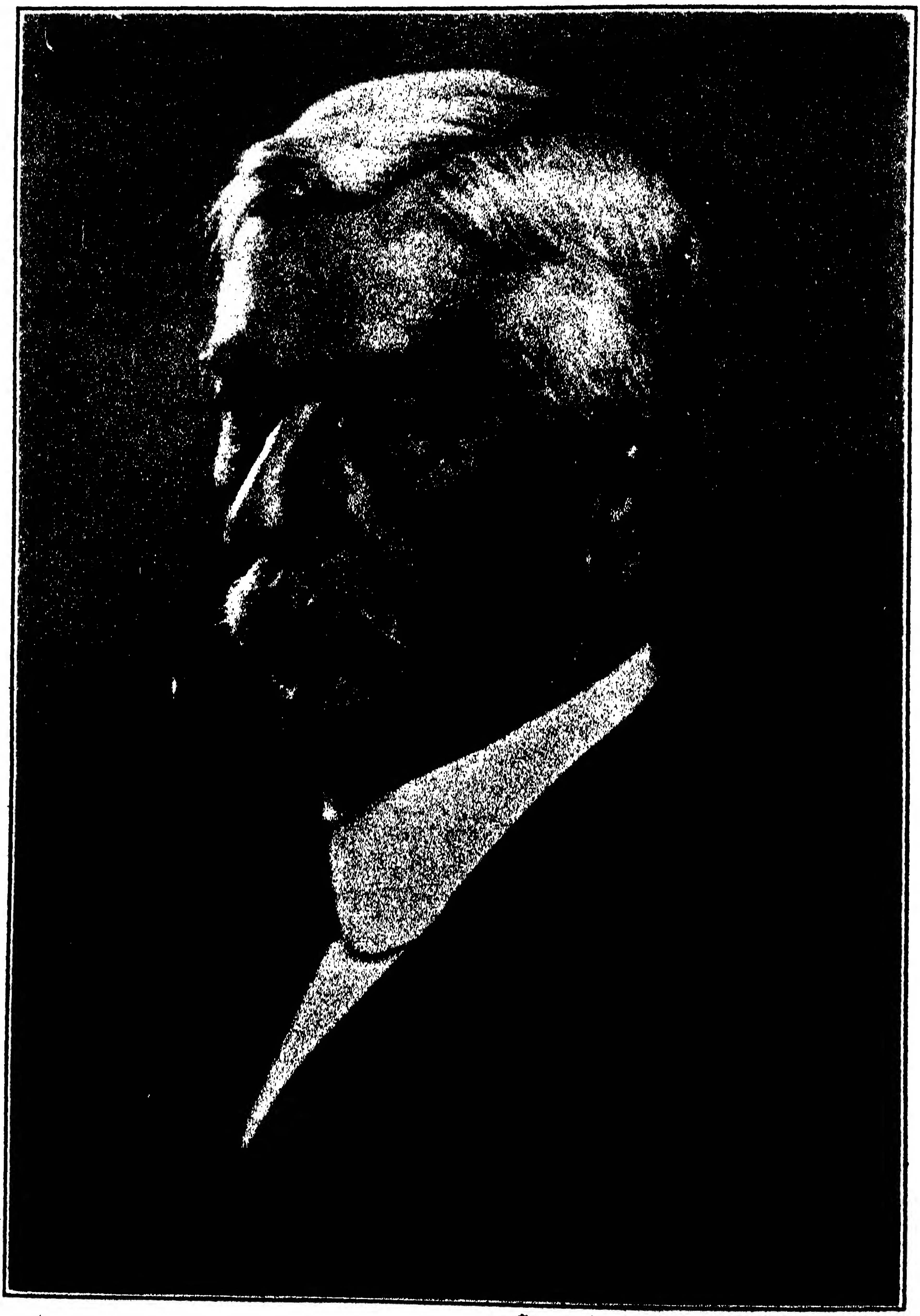
THE suppression of yellow fever, malaria and dysentery in the Panama Canal Zone is one of the triumphs of modern medicine, and General Gorgas, under whose direction the work was accomplished, symbolises more completely perhaps than any one else the control of disease by science and the applications of pathology. The war had one mitigation in that the death rate from disease was lowered to an extraordinary extent, and here again General Gorgas, as the surgeon general of the United States Army, represents this great achievement. He thus attained worldwide recognition and his death in London on his way to Africa is a cause of general regret.

Gorgas, born in Mobile, Alabama, in 1854, came from one of the historic families of the South. His grandfather was governor of Alabama, and his father, General Josiah Gorgas, was one of the West Point trained officers of the Confederate Army. He was graduated from the University of the South and from the Bellevue Hospital Medical College, and became an army surgeon in 1880. He saw service in Florida, in the West and on the Mexican border, and had risen to the rank of major in 1898, when he was with the expedition against Santiago. Thence he was sent to Havana to be the chief sanitary officer of that city during the American occupation.

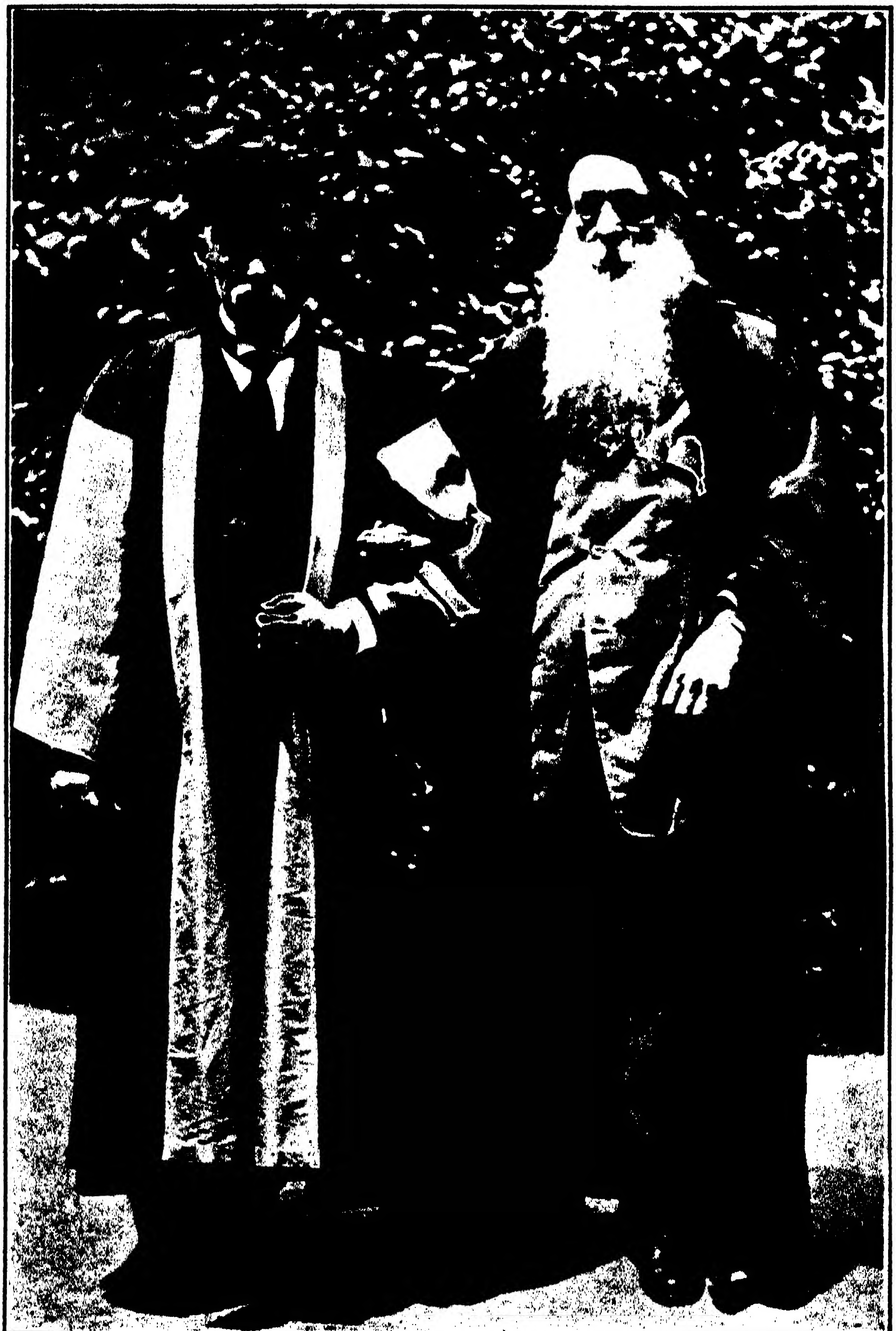
Cuba was a center of yellow fever and Dr. Carlos Finlay of Havana had proposed the theory that mosquitos were the carriers. The truth of this theory was proved and many of the conditions of infection determined by the American Army Commission, consisting of Reed, Carroll, Agramonti and Lazear. Immediately following this investigation and based upon its scientific findings, Gorgas succeeded in practically eliminating yellow fever in Havana and throughout the island.

Congress, in recognition of this work, in 1903, by special act made him colonel and assistant surgeon general, and then, a year later, he was sent to Panama, becoming chief sanitary officer of the Canal Zone, in 1904, and a member of the Canal Commission in 1907. In the days of the old French company, which attempted to build the Panama Canal, tropical diseases annually claimed one fourth of all its workers. The French were powerless before this pestilence. When Gorgas became general sanitary officer of the Canal Commission the annual death toll had been reduced, but it was still difficult to obtain the vast army of workmen necessary and to care for those disabled by malaria, yellow fever and dysentery. In nine years, by a systematic campaign for the destruction of the mosquito as the carrying agent of disease, and by other sanitary measures, Gorgas virtually drove these diseases from the Isthmus. When he gave up the work, deaths among the Canal workers had been reduced to five per thousand annually.

While in the Canal Zone, Gorgas visited Guayaquil and mapped out a plan to rid that city, long known as the "pesthole of the Pacific," from the yellow fever scourge, and his plan was in process of execution when the war began. In the winter



General William Crawford Gorgas



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DR. RAPHAEL PUMPELLY, THE GEOLOGIST AND EXPLORER, WITH DR. W. B. SCOTT (ON THE LEFT), PROFESSOR OF GEOLOGY AND PALEONTOLOGY AT PRINCETON, AT THE TIME THE DEGREE OF DOCTOR OF LAWS WAS CONFERRED ON DR. PUMPELLY BY PRINCETON UNIVERSITY.

of 1913, he went to South Africa, at the invitation of the Chamber of Mines of Johannesburg, to investigate the high death rate from pneumonia among the natives working in the mines of the Rand. By applying the army methods of increasing the air space of sleeping quarters the death rate was materially lowered.

Gorgas was appointed surgeon general of the U. S. Army on January 16, 1914, and was given the rank of major general in 1915. In 1916, he spent several months in South America in making a preliminary survey of localities still infested with yellow fever, the "endemic foci" of disease, for the Rockefeller Foundation. Upon his retirement from active duty in the Army in the fall of 1918, he resumed this work and had just started upon an investigation of the African foci at the time of his death.

THE SUPPLY OF PLATINUM

THE London *Times* discusses the world's supply of platinum limited by the demands of war and the failure of the Russian mines. Since this metal was described and named as new in 1750 by an English physicist, Sir William Watson, its singular properties have led to a continuously increasing demand. It is slightly heavier than gold, and, like gold, is very ductile and malleable. It resists all acids except *aqua regia*, and mixtures generating chlorine. Very large quantities of it are used in modern dentistry, and during the war munition factories absorbed all that could be obtained. The jeweller prefers it to gold or silver as a setting for precious stones, and it is a component of many of the most costly examples of his art. The chemist in his laboratory requires it for ladles and beakers, for retorts and crucibles. Makers of incandescent lamps, electricians, and scientific instrument makers all require it. Platinum has the curious property of absorbing large quantities of hydrogen and other gases, which in this occluded condition display a special activity. It is therefore employed in chemical industry as a catalyzer, that is to say, as an agent which excites chemical changes into which it does not itself enter. Even before the war, the relatively limited supply of the metal was unequal to the demand. The price rose rapidly. A dozen years ago platinum was 20 per cent. more valuable than gold. In 1914 it was more than twice the price of gold. In 1918 an ounce was worth five ounces of gold. After the armistice there was a slight fall, probably due to the liberation of supplies that had been withheld, but now, although gold itself has appreciated, platinum has eight times the value of gold. There is a possibility that new sources may be discovered, because it has a wide distribution usually in association with auriferous deposits. There are traces of it in the sands of the Rhine, in Lapland, Norway, and near Wicklow, in Ireland. It occurs in appreciable quantities in Honduras, Columbia, Brazil, Mexico, the United States, and British Columbia. It has been found in Borneo, Australasia, the Transvaal, Madegascar. But 90 per cent. of the world's production used to come from the Ural Mountains, where it is relatively abundant, and so easily worked that other sources have not yet been seriously exploited. In the early years of last century over a million three-rouble pieces were minted, then worth about ten shillings; now, if they could be found, worth at least £12. Efforts are being made to increase the production in Colombia; but, if Russia ever gets to work again, she will find that her platinum deposits are worth many goldmines.

THE DETECTION OF PLATINUM THEFTS

At the St. Louis meeting of the American Chemical Society a communication was presented from Dr. W. F. Hillebrand regarding the apparently organized thefts of platinum ware that are taking place throughout the United States, with the suggestion that a committee be appointed to consider whether or not legislation might not be recommended to Congress which would assist in controlling the matter. The council voted that such a committee be appointed, and the president appointed R. B. Moore, of the Bureau of Mines, Washington, D. C., Chas. H. Kerk, of J. F. Bishop and Company, Malvern, Pa., and Geo. F. Kunz, of Tiffany and Company.

The news service of the American Chemical Society has issued a bulletin describing the arrest of two men while attempting to dispose of 280 troy ounces of platinum "sponge," the porous state of the metal. They had left small lots with two different firms who, having circulars concerning various thefts, notified the authorities. The Bureau of Standards last March had lost 73 ounces in the form of laboratory ware valued at nearly $11,000, while in December, 1919, the Roessler and Hasslacher Company of Perth Amboy, had missed $5,000 worth of the metal in the form of sponge. Several universities had also complained of platinum thefts.

The exact composition of definite consignments of platinum is fairly well known to chemists, the slight variations being due to traces of other substances, such as iridium. Chemical analysis indicated that the seized supply had come neither from the New Jersey plant nor from the laboratory of the Bureau of Standards. In its quality, it closely resembled the stocks at the War Department plant in Nitro, West Virginia, where the inventory showed there should be 5,800 ounces of sponge, and also the stock of 13,800 ounces at a government military plant at Jacksonville, Tennessee. As some of the platinum at Nitro was known to contain a large percentage of palladium, that supposed to be stolen seemed to have come from Jacksonville. There the metal was of exceptional purity as it contained 99.58 per cent. of platinum, with slight traces of iridium, rhodium and iron. Its texture was uniform except that here and there were lumps of a yellowish brown substance, which on ignition yielded platinum sponge and gave off fumes of chlorine. It was learned that an order had been given at Jacksonville to turn back large quantities of platinum chloride into sponge. Then came a thorough search. In eighty-six cans in the safe was found a substance supposed to be platinum, which on examination proved to be a mixture of mercury with ordinary moist dirt.

RETIREMENT OF CIVIL SERVICE EMPLOYEES

The act providing for the retirement of civil service employees, including scientific men in the government service, is now effective. It applies to employees who have been in the classified service 15 or more years and who have reached the age of 70 years (65 years in the case of mechanics). Employees eligible for retirement are divided into six classes depending on length of service, and the maximum and minimum annuities in each class are specified by law, being contingent on the average annual basic salary for the last 10 years of service. The classes, maximum rates and annuities are as follows:

A. Service, 30 years or more; annuity, 60 per cent. of salary; maximum, $720; minimum, $360.

B. Service, 27 years; annuity 54 per cent. of salary; maximum, $648; minimum, $324.

C. Service, 24 years; annuity, 48 per cent. of salary; maximum, $576; minimum, $288.

D. Service, 21 years; annuity, 42 per cent. of salary; maximum, $504; minimum, $252.

E. Service, 18 years; annuity, 36 per cent. of salary; maximum, $432; minimum, $216.

F. Service, 15 years; annuity, 30 per cent. of salary; maximum, $360; minimum, $180.

Employees to whom the retirement provisions of the act apply shall, within 90 days of the passage of the act or within 90 days after reaching the retirement age, be automatically separated from the service. In cases where the responsible administrative officers certify to the Civil Service Commission that employees who have reached the retirement age but by reason of efficiency and willingness to remain may be advantageously continued in the public service, such employees may be retained for successive terms of two years.

Beginning with August 1, 1920, there will be withheld each month 2½ per cent. of the basic salary of each employee in the classified service.

SCIENTIFIC ITEMS

We record with regret the death of Frank Shipley Collins, an American authority on the algæ, of Leonard Doncaster, recently elected professor of biology at Liverpool, of Augusto Righi, the Italian physicist, and of Clement Arkadievitch Timiriazeff, emeritus professor of botany in the University of Moscow.

The Royal Society of Arts has conferred its Albert Medal on Dr. A. A. Michelson, professor of physics in the University of Chicago.—Cambridge University has conferred the honorary degree of doctor of laws upon Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research.

On the recommendation of the National Academy of Sciences the Barnard medal for meritorious service to science has been conferred by Columbia University on Professor Albert Einstein, of Berlin, in recognition "of his highly original and fruitful development of the fundamental concepts of physics through application of mathematics."—The Willard Gibbs medal has been presented to Dr. Frederick G. Cottrell, director of the United States Bureau of Mines, from the Chicago Section of the American Chemical Society.

Professor John C. Merriam, of the University of California, was elected president of the Carnegie Institution of Washington on May 25, to succeed Dr. R. S. Woodward, who will retire at his own request at the end of the year, after sixteen years of service. Dr. Merriam is professor of paleontology and dean at the University of California. — The National Research Council has elected as chairman for the year beginning on May 1, Dr. H. A. Bumstead, professor of physics and director of the Sloane physical laboratory at Yale University, and as permanent secretary Dr. Vernon Kellogg, professor of entomology, at Stanford University.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1920

THE POEM OF THE PHILOSOPHER THEOPHRASTOS UPON THE SACRED ART: A METRICAL TRANSLATION WITH COMMENTS UPON THE HISTORY OF ALCHEMY

By Dr. C. A. BROWNE

NEW YORK CITY

AMONG the remains of Greek literature that have come down from the Byzantine period are four poems in iambic verse upon the divine or sacred art. These poems, in the fifteen or more manuscripts which are preserved in different libraries of Europe, form part of a large collection of works upon alchemy. Most of the prose manuscripts of this collection were edited and translated by the French chemist Berthelot in 1888. The four poems, although a part of Berthelot's original plan, were not included in his edition of the Greek alchemists and, except for a meager summary of their contents by Reinesius in 1634 and a few brief extracts by Hoefer in his "Histoire de la Chimie" in 1866, no efforts have been made to give a rendering of their contents in any modern language. A study of these poems has recently been made by the writer and as they throw considerable light upon the history of Greek science in its later days, the following commentary and translation of the poem of Theophrastos are given.

The four poems, which appear in the different collections under the names of Heliodoros, Theophrastos, Hierotheos and Archelaos, usually in the order given, resemble one another so much in peculiarities of language and meter that they were undoubtedly composed under similar influences. The resemblances are so striking that Reinesius regarded the poems as the work of a single author and as nothing more than versification of different parts of the long prose work of Stephanos, who wrote in the reign of Emperor Heraclius (610 to 641 A.D.). The imitations of Stephanos in style and language are unmis-

takable and the poems must have been composed after his time. The earliest collection of the poems, the Codex 299, in the library of St. Mark at Venice, is written in a hand of the eleventh century. This codex refers again to a still earlier collection that is lost. Without discussing further the interesting questions of authorship, we are probably safe in saying that the poem of Theophrastos was composed by a Byzantine sophist or schoolman some time between the years 700 and 900 A.D. All four poems, in fact, celebrate the importance and learning of these sophists, which term in the days of the Greek Empire was one of honor and not of reproach. Theophrastos[1] begins his poem with the following eulogy:

We sophists, and the rhetoricians too,
Are fortunate and lead a life most wise;
We know the nature of created things,
The kinds of elements, and understand
How, by close union each to each, they tend
To one new form, most fair and wholly strange,
With brilliant splendor filled, its make-up such
That it bestoweth wealth and great reward.

The union of the elements into a new wealth-bringing combination has always been the one great aim of alchemy. Theophrastos, however, in order to dispel the belief that he and his fellow sophists were only worshipers of mammon, hastens to add that their chief object in life was to train new converts in the path of wisdom.

But most of all we wish with one accord
All mortals to be taught and disciplined
And trained in wisdom of the sophist school,
That they may shape themselves to perfect men,
That they may know the bounds of Nature's realm,
(How all things thrive and mix and interweave)
And last that they may nothing speak except
What words the wise old masters used to say.
Those masters urge all mortals who are wise
To be instructed in the mystic lore
Of sacred rites, whose meaning they proclaim
By actions rather than by words of mouth.

His introduction finished, Theophrastos proceeds to give a brief account of the skill of the sophists in the different sciences. He begins most naturally with astrology, for the teachers of that time were firm believers in the power of starry influences.

We, who foretell just where the stars shall be,
Who know their natures, heights and intervals,
Their occultations, when they rise and set,

[1] The Greek text, upon which the translations of Theophrastos and other Byzantine alchemists in this paper are based, is that given in Ideler's "Physici et Medici Græci minores," Berlin, 1841.

Their measured bounds and what their orbs portend,
Do not misread their signs, though far away,
For when assisted by a knowing mind
Our sense of vision sees them as they are.
We know the truth of what is in the sky
Above and are not ignorant of what
Is there performed, for we perceive it all
And make it evident to mortal minds,
As their experience can testify.

Next in importance after astrology Theophrastos places medicine. In the decadence of Greek science, astrology and medicine were always linked together. The Perignostics of Hermes Trismegistos give in great detail the influence of the planets upon the courses of disease.

The most important branch of Byzantine medicine was prognosis, which was elaborated to such a degree that physicians professed to indicate sickness long before the patient felt any of its symptoms. Copious treatises upon diagnosis have come down from Byzantine writers, who describe with great minuteness methods for examining the urine and feces, or for determining the patient's condition from the beatings of his pulse. In the treatment of disease the regulation of diet played a most important part and elaborate regimens were prescribed for the sick for each season and month of the year.

Yet more than this, the causes we reveal
Of each affliction in the body's frame;
Experimentally our school explores
The science, art and ends of medicine,
With such success that our prognosis shows
What sicknesses are destined to appear
And what is best to cure or ward them off;
Its findings also lead us to foretell
An end of life from sickness far from home.

Leaving medicine Theophrastos next briefly relates the investigations of the sophists in the vegetable, mineral and animal kingdoms.

Not only has our wisdom known the ways
By which to check each illness and disease,
—Prodigious wonders even though they be—
But with exactness we describe the flowers,
(Their qualities, their mixtures and their kinds),
And taste of juice and substances of plants.
Each class of growing herbs has been portrayed
For our prognosis and with words exact,
We also know the hues and kinds of stones,
The places where the metals are produced
And all their properties both good and bad.
The many kinds of creatures in the sea
Are known to us and all their many forms;
We teach mankind their natures, good and bad,

How some to use and others to avoid.
Nor do we slight the race of gay-hued birds,
Those strange in form and those who kill their kind,
Those who by nature are of use to man,
And so contribute to the joy of life.
Each class and race of reptiles we describe,
And so all living things find place within
Our catalogue. Nor have we falsified
In anything, for every word is true.
All we have said or shown to mortal men
Is for their use and happiness in life.

But the sophist's career, which Theophrastos has thus far painted in brightest color, was not one of unalloyed happiness. Many of the prose writers among the Greek alchemists dwell upon the opposition which was provoked by their ideas regarding the transmutation of metals, but few of them are as bitter in the denunciation of their critics as the poets. No better example can be found than Theophrastos of that proverbial sensitiveness which Horace states has always characterized the fretful tribe of poets.

How then can those vile critics censure us,
They who in secret learning are inept,
And who in sophic wisdom have no share?
How can they say we sophists speak untruths
With their own minds so pitifully maimed
They give no thought or care to things divine?
They ask how gold is ever to be made,
How that can change which has a nature fixed,
Placed there of old by God the demiurge,
Who formed its substance never to be moved
From that position which from early time
Was its abode and destined resting place;
They say gold thus abides, nor suffers change,
For naught can be transmuted from the class
Or species where its origin took place.
They who speak thus but trifle with their minds
And nothing say that bears the stamp of truth.

The quarrel between the alchemists and their critics involved the old question of the fixity or transmutability of genera and species. It dated back to the time of Aristotle, who was the first to make the distinction between a material cause and a formal cause. The critics of alchemy insisted that matter was unchangeable, that lead always remained lead as gold always remained gold and that the gulf between these two metals was an impassable one.

To the argument for the unchangeableness of matter the alchemists gave complete assent. They replied to their critics:

We agree with you that matter is unchangeable, but you forget that it is not matter which we seek to change but only the form in which this matter is cast. The material substance or stock (φύτη) of lead, gold and

other things is one and unchangeable, and the object of our endeavor is simply to pour the matter from the form of lead into the form which our human perceptions recognize as gold. Just as an artist can take the bronze of an ugly vessel and recast it into a beautiful vase. But if the idea of transmutation seems so irrational, take the case of the sun. He is always the same, yet by his movements along the ecliptic he produces the change of seasons which pass from extreme cold to extreme heat and from extreme moisture to extreme dryness.

The comparison of transmutation with the change of seasons was a favorite one with the Greek alchemists, for it rested upon one of those etymological subtilties which always appealed to the Hellenic mind, the word τρόπη meaning both alteration and season (originally solstice). This play upon words is followed by Theophrastos.

But we will show the end of this our art,
An end most useful and most quickly learned,
For nothing strange it needs save that one stock
From which all things by Nature are produced.
From Time's four transformations learn the way
By which the work most skilfully completes
The transformations of sophistic art.
The winter, cold and moist, controls the frost;
By him the fleeting clouds are borne on high
To drench the earth and quicken seeds to life;
Three months elapse before his time expires.
Next Spring, a season moist and warm comes in;
By her the earth is made to bloom with flowers
Of every kind; her course is also run
When three more months their transformation bring.
Next Summer, warm and very dry, appears;
By her Earth's bosom is released from damp
And, warmed from chilliness, is made to bear;
Her period in three more months is run.
The Autumn quickly comes upon his way,
A season dry and cold in which alas
The beauty of the flowers is all destroyed;
His rapid course in three more months is passed.
Through these four transformations runs the sun;
He makes his circuit in the dozen months
Which form the year and sheds his light on all
Beneath the sky. The splendor of his beams
Fills all the earth with mild increasing warmth;
With rapid course he summons things to life
And makes with gentle heat all trees to bud.
From him the moon receives her gleaming light
And all the wandering stars, the planets seven,
And likewise those whose shining orbs are fixed.

The argument of Theophrastos about the seasons is a brief summary of that given in the fifth praxis of Stephanos, who states that the four elements, earth, water, air, fire, in their cycle of the year form twelve combinations of triads in four

sets. There is thus one triad of elements for each month and a set of three triads of similar elements for each season. The arrangement of this cycle of elements is illustrated by the following diagram.

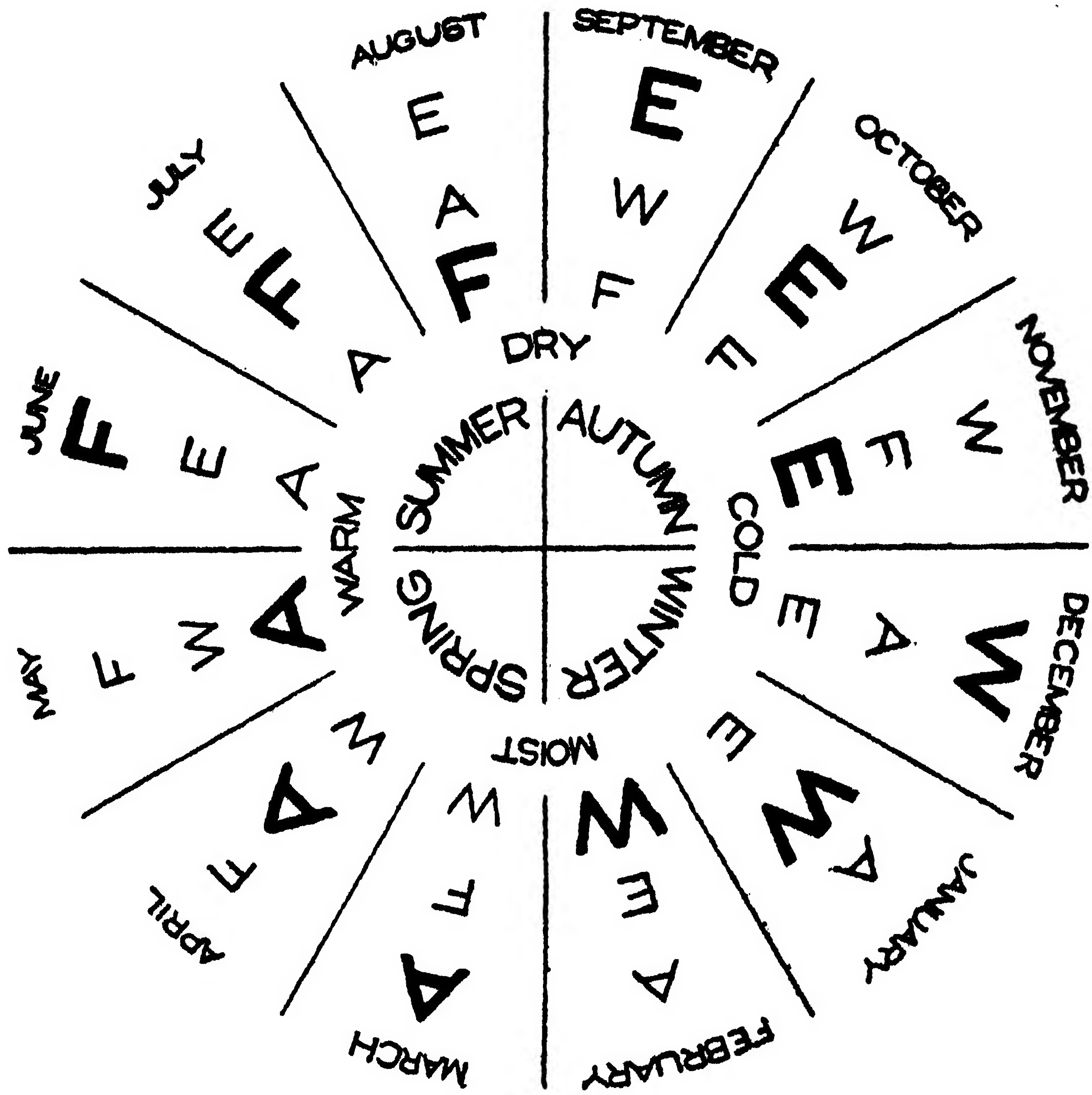

DIAGRAM OF THE YEAR'S CYCLE OF ELEMENTS (constructed from Stephanos).

The Elements Earth, Water, Air, Fire are represented by their initials E, W, A, F; the governing element of each season and month is in large letter. Fire is absent in winter, Earth in spring, Water in summer, Air in autumn. Commencing on the middle circle in Dec. Air goes to the outer circle for Jan., Feb., Mar., crosses in April to the inner circle for May, June, and July and finishes again on the middle circle in August. Then Water follows a similar path, to be succeeded by Earth, the final interweaving circuit of the three rings being completed by Fire.

The quality Moist is common to winter and spring, Warm to spring and summer, Dry to summer and autumn, Cold to autumn and winter.

Theophrastos, in the last line, expresses the belief, common in ancient times, that the fixed stars, as well as the moon and planets, received their light from the sun. As the production of metals, precious stones, etc., within the earth was believed by the ancient alchemists to be due to emanations from the heavenly bodies and, as the light of the moon and planets was received from the sun, the generation of the metals and precious stones could thus be referred to a single influence.

So understand the work, how to refer
The four mutations to one simple form
And from the four to make the work complete,
Seven colored, even as the planets seven,
Whence Nature gets her species, kinds and forms,
Whence Luna's metal takes a whitened hue
And whence proceeds the yellow principle
(That gives a second splendid purple tint)
Which brightening all bodies tinges them
The brilliant golden color of the sun.

Theophrastos having outlined the theory of his art, next takes up its practical execution. His description of the process of gold-making, however, is so obscured by allegory that it is a hopeless task to follow him without referring to the older works.

Transmutation, although described by the Greek alchemists as a conversion of base metals into silver and gold, is everywhere designated as a process of coloring or tingeing. Several methods of tingeing the base metals were employed, but only two of these will be described.

The first method consisted in giving the metal a wash with an amalgam of silver or gold. Upon heating the coated metal the mercury was expelled and a thin film of silver or gold remained. This receipt for silvering, or gilding, metallic objects was an old one. It was a favorite with counterfeiters and was one of the methods resorted to by the Roman Emperors when they wished to debase the coinage. In the practical receipts we find no suggestion of transmutation when this method was used. It is only with the alchemists that the process acquired an additional mystical interpretation. Mercury, which was volatile, was a spiritualizing agent and the leaven, or seed, of precious metal when placed therein had the power of transmuting the baser metal into its own nature. This was illustrated by the sayings.

Just as the yeast of bread can leaven a large mass of dough, so does a little silver or gold act. He who sows wheat produces wheat and harvests it, in the same way gold produces gold and silver produces silver.

In the first method of tingeing metals the coloration took place only upon the surface. In the second, and to the alchemists the most important, method of tingeing the change in color was effected throughout the whole body of metal. The earliest writers drew a clear distinction between these two methods, the Pseudo-Democritos being among the first to condemn those who supposed that mercury should act only upon the surface. The means by which the Greek alchemists claimed to transmute the entire body of base metal into gold can only be understood by going back to the oldest receipts.

When the Greeks under Ptolemy took possession of Egypt they found in the temples a vast collection of practical receipts which were jealously guarded by the Egyptian priests. These ancient books, which formed a large collection of works upon pharmacy, metallurgy and other arts, were ascribed by the Egyptians to Thoth whom the Greeks identified with their god Hermes. These books have all been lost with the exception of one manuscript upon medicine, the so-called Ebers papyrus written about 1500 B.C., which contains various pharmaceutical and magical prescriptions for treating diseases. The mention in this manuscript of such substances as copper, lead, iron, stibium, asem (a gold-silver alloy), sulphur and soda and the reference to such operations as roasting, cooking, melting, extracting and filtering shows that the early Egyptians were familiar with the products and processes of practical chemistry. It is unfortunte that none of the Hermetic books upon metallurgy have survived. Allusions to these books by Olympiodoros and other Greek writers show, however, that the Egyptian priests possessed a vast amount of information upon the smelting, alloying and coloring of metals. Translations of some of these Hermetic receipts have no doubt been incorporated into the collections of the Greek alchemists.

Although the ability to transform the base metals into silver and gold was attributed to the Egyptians by the Greek alchemists, we find no historical mention of this until about 290 A.D. when the Roman Emperor Diocletian destroyed the books of the Egyptians upon the chemistry of gold and silver. The incident is thus commented upon by the historian Gibbon:

> At the same time that Diocletian chastised the past crimes of the Egyptians, he provided for their future safety and happiness by many wise regulations, which were confirmed and enforced under the succeeding reigns. One very remarkable edict which he published, instead of being condemned as the effect of jealous tyranny, deserves to be applauded as an act of prudence and humanity. He caused a diligent inquiry to be made "for all the ancient books which treated of the admirable art of making gold and silver, and without pity committed them to the flames; apprehensive, as we are assured, lest the opulence of the Egyptians should inspire them with confidence to rebel against the empire." But if Diocletian had been convinced of the reality of that valuable art, far from extinguishing the memory, he would have converted the operation of it to the benefit of the public revenue. It is much more likely that his good sense discovered to him the folly of such magnificent pretensions, and that he was desirous of preserving the reason and fortunes of his subjects from the mischievous pursuit. It may be remarked that these ancient books, so liberally ascribed to Pythagoras, to Solomon, or to Hermes, were the pious frauds of more recent adepts. The Greeks were inattentive either to the use or to the abuse of chemistry. In that immense register, where Pliny has deposited the discoveries, the arts, and the errors of mankind,

there is not the least mention of the transmutation of metals; and the persecution of Diocletian is the first authentic event in the history of alchemy.

The question "if the Egyptians could make gold why did Diocletian not avail himself of the knowledge?" has puzzled many a writer. We know that the financial condition of the Roman Empire at this time was a desperate one. The argenteus, of which sixty were originally coined from a pound of silver, had, under succeeding Emperors, been continually debased. In the reign of Gallienus the argenteus consisted only of base metal plated with silver. The final limit was reached when it was made of copper and counterfeited to resemble silver by a wash of tin.

Diocletian adopted heroic remedies to relieve the financial condition of his empire by regulation of taxes, fixation of prices and restoration of the silver coinage. From the information contained in papyri, that have recently been published, we now know that Diocletian's destruction of the chemical treatises of the Egyptians was directly in line with these reforms. Counterfeiting had reached a higher state of perfection in Egypt than in any other part of the Roman Empire and when the practical-minded Emperor discovered that the chemical books of the Egyptians gave detailed information for imitating silver and gold he very properly burned these treatises as one of the causes of the Empire's financial troubles. Stringent measures were taken to enforce these regulations and the counterfeiters, who previously worked in the open, were now compelled to labor in secret. Their practical knowledge of the art was rewritten in an obscure enigmatic language which if discovered would deceive the military inspectors. This obscurity was still further enhanced by the decline of the metallurgic arts and the influence of Greek, Jewish and Gnostic mysticism, until what in the older days was bluntly admitted by the practicians to be a fraud was now acclaimed by the speculative mystics to be a transmutation.

This view of the origin of alchemy which was advanced by Berthelot[1] has been amply confirmed by the publication in re-

[1] "It was thus that the workmen, accustomed to compound alloys resembling gold and silver with such perfection that at times they deceived even themselves, ended by believing in the possibility of an actual creation of these metals." (Berthelot, Alchemistes Grecs, Introd., p. 73.) The Upsala papyrus was not published until 1913 (Papyrus Græcus Holmiensis, Upsala A. B. Akademiska Bokhandeln). Could Berthelot, who saw the great importance of the Leyden papyrus, have only lived to read the Upsala papyrus, he would have seen the most complete verification of his views. Lagercrantz, in his scholarly edition of the Upsala papyrus, discusses the whole question exhaustively and adopts the same view of the

cent years of two Greek papyri belonging to libraries in Leyden and Upsala. These papyri, which have been described as twin-brothers, were discovered in Egypt nearly a century ago by natives, while engaged in the plunder of tombs, but it is only lately that their contents have been made known. The two documents consist of over 250 receipts for purifying and treating metals, for preparing alloys, for counterfeiting gold and silver, for imitating pearls, emeralds, sapphires and other precious stones and for preparing colors and dyes. Only a few of the receipts for counterfeiting gold and silver will be quoted.

To adulterate gold (χρυσοῦ δόλος). An equal part of misy and Sinopic rouge to an equal part of gold. Put the gold in a furnace and when it is bright add each of the other ingredients. Take out and let cool when the quantity of gold is doubled. (Leyden papyrus, Rec. 17.)

To make silver (ἀργύρου ποίησις). Clean white soft tin four times, melt six parts of the same with one mina of white Galatian copper. It becomes prime silver that will deceive even skilled workmen who will not suppose it to be made by such a treatment. (Upsala papyrus, Rec. 3.)

Another receipt. Add six parts of purified tin and seven parts of Galatian copper to four parts of silver and the resulting product will pass unnoticed for silver bullion. (Upsala papyrus, Rec. 4.)

The receipts just quoted are all manifestly fraudulent as they are stated to be in the directions. One other receipt for making silver has an interesting significance, as it makes use of mercury, the spiritualizing medium of the later alchemists.

To make silver. Purchase coals such as the coppersmiths use and steep them in vinegar for one day. Then take one ounce of copper, fix it well with alum and melt in this condition. Then take eight ounces of mercury and empty the same into poppy extract. Take also one ounce of silver and, having incorporated these ingredients together, melt. (Upsala papyrus, Rec. 8.)

The Leyden and Upsala papyri were written apparently towards the close of the third century and are to be regarded as prototypes of the later alchemical receipts, the earliest manuscript of which dates back to the eleventh century. The connection of the two classes of documents with one another is unmistakable. The papyri refer to Democritos and Aphrikanos, who are mentioned repeatedly by the alchemists. Many

fraudulent origins of alchemy. "The Egyptian priests are therefore to be regarded as the oldest representatives of the art of adulterating gold, silver, precious stones and purple. Since the preservation of receipt books in the temples is expressly mentioned, then in all probability we should regard these places also as workshops for counterfeiting. If any one should think such a calling not to conform exactly with the virtues of priesthood, we would reply by saying that we should not entertain too exaggerated ideas of the morality of this profession. Moreover an outward show of uprightness could easily be given to operations from which the public at large was naturally excluded."

of the receipts in the two collections are identical and the occurrence of the term an inexhaustible cake (ἀνέκλειπτος μᾶζα) of metal in both the papyri and the alchemists shows a certain community of origin.

The two papyri no doubt belong to the class of chemical books which Diocletian destroyed, the accident of burial, or concealment, having secured their preservation. They offer a good illustration of the practical receipts of the Egyptians before they were obscured by the allegorical interpretations of later mystics.

Under Christian influences this allegorizing tendency was further accentuated. The technical term for coloring is βάπτειν, to dip, and the close resemblance of this word to its cognate, βαπτίζειν, to baptize, conveyed a spirit meaning of the process to the Christian alchemists of the Byzantine era. Allusions to the New Testament became frequent. Chemical processes are represented under such terms as baptism, bodily death and resurrection, while the whole language is permeated with mystical expressions. Each metal, the same as man, becomes endowed with the triple hypostacy of body, soul and spirit. "The aim of our philosophy," writes Stephanos, "is the separation of soul and body." Divest lead or copper of its soul and spirit, endow the resulting body with a soul and spirit of a higher type and the result is gold. The change from the black of lead or the red of copper to the yellow of gold could not, however, be accomplished directly. The base metal must first be brought to the whiteness of silver before projection of the stone can produce gold. This is indicated in the lines of Theophrastos:

The white, augmented thrice within a fire,
In three day's time is altogether changed
To lasting yellow and this yellow then
Will give its hue to every whitened form.
This power to tinge and shape produces gold
And thus a wondrous marvel is revealed.

The great agent of transmutation was the stone. "It is found," said Avicenna, "in the dirt of streets and is trodden under foot by men." The Greek alchemists were no less explicit. "It can not be bought with gold," said an unknown prose writer, "yet God has given it freely to beggars." Zosimos, a Greek of Panopolis, described it as "a stone yet not a stone, a thing despised yet full of honor, of many forms yet shapeless, a thing unknown yet familiar to all, of many names yet nameless." The description of Theophrastos is equally obscure.

Though not a stone, it yet is made a stone
From metal, having three hypostases,
For which the stone is prized and widely known;
Yet all the ignorant search everywhere
As though the prize were not close by at hand.
Deprived of honor yet the stone is found
To have within a sacred mystery,
A treasure hidden and yet free to all.

The symbol of chemical change from the earliest days of alchemy has been the fiery dragon or salamander. In the form of a dragon devouring its tail and bearing the mystical motto of three words and seven letters, ἓν τό πάν, "The All is One," it was used by the Greek alchemists to typify the unity of matter. It was the symbol of the never-ending cycle of the elements; the appearance of matter is always changing, yet its substance is eternally one and the same.

The first step in the process of transmutation, the process of albifaction (λεύκωσις) or conversion of the base metal into silver, is thus described by Theophrastos under the symbol of the dragon.

A dragon springs therefrom which, when exposed
In horse's excrement for twenty days,
Devours his tail till naught thereof remains.
This dragon, whom they Ouroboros call,
Is white in looks and spotted in his skin,
And has a form and shape most strange to see.
When he was born he sprang from out the warm
And humid substance of united things.
The close embrace of male and female kind,
—A union which occurred within the sea—
Brought forth this dragon, as already said;
A monster scorching all the earth with fire,
With all his might and panoply displayed,
He swims and comes unto a place within
The currents of the Nile; his gleaming skin
And all the bands which girdle him around
Are bright as gold and shine with points of light,
This dragon seize and slay with skillful art
Within the sea, and wield with speed thy knife
With double edges hot and moist, and then,
His carcass having cleft in twain, lift out
The gall and bear away its blackened form,
All heavy with the weight of earthy bile;
Great clouds of steaming mist ascend therefrom
And these become on rising dense enough
To bear away the dragon from the sea
And lift him upward to a station warm,
The moisture of the air his lightened shape
And form sustaining; be most careful then
All burning of his substance to avoid
And change its nature to a stream divine

With quenching draughts; then pour the mercury
Into a gaping urn and when its stream
Of sacred fluid stops to flow, then wash
Away with care the blackened dross of earth.
Thus having brightened what the darkness hid
Within the dragon's entrails thou wilt bring
A mystery unspeakable to light;
For it will shine exceeding bright and clear,
And, being tinged a perfect white throughout,
Will be revealed with wondrous brilliancy,
Its blackness having all been changed to white;
For when the cloud-sent water flows thereon
It cleanses every dark and earthy stain.
    Thus he doth easily release himself
By drinking nectar, though completely dead;
He poureth out to mortals all his wealth
And by his help the Earth-born are sustained
Abundantly in life, when they have found
The wondrous mystery, which, being fixed
Will turn to silver, dazzling bright in kind,
A metal having naught of earthy taint,
So brilliant, clear and wonderfully white.

With the help of the practical receipts and early prose treatises upon alchemy we are able to form some idea of the operations thus described.

It was recognized by the very earliest writers upon alchemy that the two important conditions necessary for promoting material change were heat and liquidity. Solution of the interacting substances was first necessary and to effect this solution heat and a liquid solvent were required. "Corpora non agunt nisi soluta" was a tenet of the medieval alchemists, an expression which was simply borrowed from the *ἀναλυόμενα πάντα ἐργάζεται* of the Greeks. When Theophrastos states, therefore, that the dragon is born from "warm and humid substance" and is to be slain in turn by a "knife with double edges hot and moist," we are simply to infer that the ingredients of his preparation are to be acted upon by some liquid through the agency of heat. The ingredients in this case, as in receipt No. 8 of the Upsala papyrus, are copper and silver and the acting liquid, as in the same receipt, is mercury.

Theophrastos describes his ingredients as male and female, a method of appellation common to the alchemists, who classified nearly all their substances under the one or the other of these terms. One very important male ingredient, used for the white coloration of copper, was arsenic, the word *ἀρσενικόν* in Greek meaning either arsenic or masculine. The connection of gender, however, is not always so apparent as this. Another means of differentiation was based upon the gender of

the word, planet or deity representing the substance. Thus lead and gold are always masculine whether represented under the common names μόλυβδος and χρυσός or under the planetary names Κρόνος and Ἥλιος. Copper and silver, on the other hand, are masculine under the common names χαλκός and ἄργυρος, feminine under the planetary names Ἀφροδίτη and Σελήνη. Copper, however, is stated by nearly all the alchemists to be a man, while silver is constantly referred to as copper's bride, the union of the two being symbolized as a marriage.

The mystical marriage of copper to silver was not accomplished, however, by melting. The fusing together of copper and silver into the alloy was recognized by the alchemists as a blending (κρᾶσις) and not as a uniting (ἕνωσις). For the actual union of two opposites Greek philosophic ideas required the action of an intermediary which shared the qualities of the two elements or substances. The old alchemists dwell constantly upon the necessity of this. Fire, for example, is warm and dry, while water is moist and cold. These two opposites are joined by the intermediary action of air which is warm and moist.

The intermediary agent employed in the union of copper to silver was mercury, which in some of its attributes shared the qualities of both these metals. For example, mercury in color resembled silver, while its oxide in color resembled copper. But the point upon which the alchemists placed most stress was the intermediary influence of gender, mercury being both male and female. In the Upsala papyrus we find the masculine form ὁ ὑδράργυρος in the eighth receipt and the feminine form ἡ ὑδράργυρος in the seventeenth. The same difference in gender is also observed in other technical treatises. The classic Greek writers used the masculine form, but most of the alchemists employed the feminine, although recognizing the distinction of double gender. Zosimos, for example, in one of his allusions to mercury says "it is the silvery water, the masculine-feminine (τὸ ἀρσενόθηλυ), that which is always running away and yet hastening unto its own."

The union of copper and silver is referred to by Theophrastos as taking place within the sea, the latter being a common term for the liquid metal mercury. The amalgamation is hastened by warming the vessel containing the ingredients in fermenting horse dung for twenty days. At the end of this time all traces of metal have been dissolved by the mercury, or as Theophrastos says the dragon "devours his tail till naught thereof remains."

The mixed amalgam of copper and silver, which according to Theophrastos was a speckled white, was next transferred to some form of Egyptian alembic, such as were made at Alexandria, an operation alluded to by saying that the dragon "comes unto a place within the currents of the Nile." The mixture is then heated over a gentle fire until the mercury is distilled away, this part of the operation being indicated by such terms as slaying the dragon "with skillful art within the sea," "Clouds of steaming mist ascend therefrom and these become on rising dense enough to bear away the dragon from the sea," etc. The vapors are condensed in the head of the alembic, "its nature changed into a stream divine," after which the liquid mercury is poured out into a recipient. Theophrastos here for the first time banishes allegory and calls mercury by its actual name, the sign of the waxing crescent being affixed to remove all doubt of his meaning.

During the distillation of the mercury a dross of black oxide gathered on the surface of the melted contents of the alembic, a phenomenon alluded to as the lifting out of the gall, and the removal of "its blackened form all heavy with the weight of earthy bile." The final flashing of the melted metal under the scum of oxide, which Theophrastos mentions under such terms as brightening "what the darkness hid within the dragon's entrails," is, according to Hoefer, exactly what the metallurgist to-day observes in the cupellation of silver.

The mass of metal in the alembic is then cooled and scrubbed with running water which "cleanses every dark and earthy stain." The silver-copper alloy thus obtained is described by Theophrastos as "silver dazzling bright in kind, a metal having naught of earthy taint."

The transmutation of copper to silver by the above process is described by many of the Greek alchemists as a combat or battle in which the male contestant copper is completely vanquished by the female victor silver.

Stephanos in his fourth praxis exclaims:

> Fight copper! Fight silver! Join male and female! The copper in his contest with silver is destroyed; the silver by her combination with copper is fixed. Destroy the body of copper and make it incorporeal by means of silver.

So also Archelaos in his poem causes the soul of copper to address its lifeless body:

> Thou dost not wait the female joined to thee
> In wedlock as desired. Thou dost not check
> The clash of female conflict but decay
> Awaits thy bloom from her.

It is seen from this that Mr. Kipling was not the first poet to declare, "The female of the species is more deadly than the male."

The first step of transmutation, the albifaction or λεύκωσις having been accomplished, there only remains the final step, the yellowing or ξάνθωσις, by means of which the silver is transformed to gold. This part of the process is described by Theophrastos as the second slaying of the dragon.

Then seize again this dragon changed to white
(A change divinely wrought, as I have said,
By means of albifaction twice performed)
And slaying him again with knife of fire
Draw all his blood which gushes blazing hot
And red as shining flame when it ignites.
Then dip the dragon's skin into the blood
Which issued from his belly's gory wound
(As thou wouldst dip a whitened robe in dye
Of murex purple); so wilt thou obtain
A brilliant glory, shining as the sun,
Of goodly form and gladdening the heart
Of mortals who behold its excellence.

This second slaying of the dragon is accomplished by heat alone, the agency of liquid mercury not being required. The weapon this time is "a hot knife of fire" in place of the "knife with double edges hot and moist" previously employed. The metal from the first transmutation is accordingly re-melted over a hot fire preparatory to the addition of the stone, or powder of projection, by means of which the conversion of the silver to gold is to be accomplished. This is done by drawing off the melted metal, which Theophrastos calls the blood of the dragon, and stirring into it the powder of projection, an operation which is poetically described as dipping "the dragon's skin into the blood."

The composition of this "dragon's skin," or stone, or powder of projection, was the chief subject of investigation by the medieval alchemists, who wrote countless treatises upon the subject. Without discussing any of the medieval receipts it may be said that reference to the oldest writings indicates that the so-called stone was originally a yellow powder composed of such ingredients as copper, cuprous oxide, cinnabar, litharge, yellow arsenic or orpiment, misy (a copper-containing pyrites), sory (basic sulphate of iron), sulphur, and other substances whose yellow color might be a recommendation. A certain amount of gold was also probably included to act as a seed or leaven.

In a receipt, previously quoted from the Leyden papyrus for adulterating gold, misy and Sinopic rouge are mentioned as

ingredients to be added to the gold and we have here probably a germ of the later powders of projection.

A somewhat fuller receipt is given in the Pseudo-Democritos:

Lighten the color of cinnabar by means of oil, vinegar, honey, brine or alum; then make it yellow by means of misy, sory, flower of copper, nature sulphur, or in any way desired. Project this upon silver and it will be gold.

A considerable latitude is given in these directions, as is indicated by the expression, "or in any way desired." The rigid exactness of the medieval alchemists, who permitted not the slightest deviation in character or quantity of the ingredients, is not as yet apparent.

Two very important substances, used by the Greek alchemists in projections, were the so-called molybdochalc (μολυβδόχαλκος) and aphroselen (ἀφροσέληνον). Owing to the very inexact nomenclature of the times, these words were given to a variety of products, although the terms seem most generally applied to the oxidation products obtained in refining lead-copper and copper-silver ores. The waste dust of the lead, copper and silver smelting works was especially prized by the old alchemists. This dust, described under such names as cadmia, tutia, magnesia, tephra, pompholyx, little scoriæ, etc., fulfilled the mystical requirements of the stone, "being a product of many names, of no value, found in the dust of streets and trodden under foot by men." The incorporation of metallic oxides into the tinctorial powder or stone is alluded to by Theophrastos where he says "though not a stone, it yet is made a stone from metal."

The substances entering into the tinctorial powder were obtained in many cases by subjecting the metals themselves to a process of corrosion (ἴωσις). The directions for preparing molybdochalc according to a receipt of the Pseudo-Democritos were to heat white lead, or litharge, with flower of copper, or roasted copper, or treated copper-rust until the mixture became yellow. The manufacture of some of these ingredients, according to accounts given in Dioscorides and Pliny, will be briefly described.

White Lead (Greek, ψιμύθιον; Latin, cerussa) was made as follows: plates of lead were put into jars containing vinegar and kept closed for ten days. The corrosion that formed upon the surface of the metal was then scraped off and the lead put into the vinegar again. The process of corroding and scraping was continued until the whole of the lead was consumed. The scrapings were powdered, sifted, and dried in the sun. The method thus described is about the same as the modern

Dutch process for making white lead. The white lead obtained was used as such, or else was heated in shallow pans until it was converted into the yellow or red oxides. These changes of color from the black of lead to the white of the basic carbonate and to the yellow of the oxides were of especial significance to the alchemists, for they followed the traditional order which base metals should follow in their conversion to silver and gold.

Flower of Copper (Greek, χαλκοῦ ἄνθος; Latin, æris flos) was made in several ways. In one method the fused metal was exposed to a blast of air which caused the surface to peel off in small scales. In another method the scales were formed by drenching the hot metal with water. The scales, after being powdered, had a reddish-yellow color and consisted of a mixture of metallic copper and cuprous oxide.

Roasted copper (Greek, χαλκὸς κεκαυμένος; Latin, æs ustum) was made by heating copper in closed vessels with various substances, such as sulphur, salt, alum, and vinegar. The calcined residue was then powdered in a mortar, washed and sifted. It consisted of a reddish-yellow powder and had a composition resembling that of flower of copper.

Copper rust (Greek, ἴος; Latin, ærugo) or verdigris was made by sprinkling vinegar upon copper filings or by putting plates of copper into earthern pots containing vinegar and scraping them every ten days. The scraped rust referred to in the receipt of Pseudo-Democritos was not used directly in making the powder of projection, but was treated, a process which, from a description of Dioscorides, probably consisted in heating the verdigris in a closed vessel until the basic acetate was changed into a red suboxide of copper.

The scraping of the corrosion or oxide from the metal plates, mentioned in these processes, is the operation described by Theophrastos and other alchemists as "skimming the dragon," the figurative skin, which was removed, forming the basis of the older powders of projection.

The action of the "dragon's skin," or stone or powder of projection, upon the silver-copper alloy of the first treatment would simply be to increase the copper content of this alloy and give it a golden color. The seed of gold and unchanged copper in the preparation would of course be readily taken up. The suboxide of copper has also a certain solubility in melted alloys of this kind and would help to impart a red or yellowish tint to the resultant mass of metal. Any unabsorbed ingredients, such as sulphur, orpiment, cinnabar, litharge, etc., would be either colatilized or thrown out as dross. The fused alloy after drawing off and casting probably had a yellow color

much like that of gold. It might possibly "escape detection by skillmen workmen," to use the unsophisticated language of the old receipts, and to the credulous-minded alchemists, who had forgotten the old Archimedean method for determining the purity of metals, might easily pass for gold so pure that even "the treasuries of kings did not possess the like."

A final question, which remains to be considered, is the quantity of tinctorial powder that was used for projection. In the Leyden papyrus the receipt for adulterating gold prescribed "an equal part of misy and Sinopic rouge," and we can infer from other practical receipts that the amount of material used in the early days for tingeing metals the color of gold was considerable. In one Greek manuscript the directions state: "As to the weight of the projection, in the first operation one weight is projected into one weight; in the second one weight into a thousand weights; in the third one weight into a million weights." We know from the old writings that the process of projection was frequently repeated and with each repetition of the process the quantity of powder was diminished.

When the old practical receipts became permeated with mysticism, the idea of a seed or leaven, which could transform an almost unlimited amount of base metal, got the upper hand. The quantity of powder was reduced until in the middle ages it was held that one grain of powder could transmute whole oceans of base metal into gold. By thus diminishing the quantity of powder the coloration produced by the older methods of projection was no longer obtained and the composition of the powder was held to be lost.

The subject of alchemy offered the Byzantine schoolmen a convenient theme for the exercise of rhetorical flourishes and Theophrastos next proceeds in a kind of litany to tell how the fortunate ones, who have been enriched by alchemy, express their appreciation.

They praise the gift with wise and joyous words
As one divinely sent and great in worth;
And thus they speak and voice their thankfulness.
O work divine, well-pleasing and concise!
O beauty brilliant with an aspect clear!
O marriage and conjunction most renowned!
O husband in a single union joined!
O wife united by affection deep!
O offspring famous and with glory filled!
O progeny of splendor, light and worth!
O robe with gold and silver overlaid!
O double-folded mantle bright as snow!
O metal which with gleaming silver teems!
O clear refreshing river of the sea!

O water than the loosened earth more free!
O ether rising far above the earth!
O clouds transformed from blackness into white!
O brilliant colored glory of the heaven!
O light which shines to all beneath the sky!
O system and bright circuit of the stars!
O lunar light reflected from the sun!
O sun whose darting beams engender gold!
From these the work of every sage begins
To reap in practise some deserving end;
In thee appears the object of our search;
Thou shinest scattering thy wondrous light,
A treasure most desired, all filled with pearls;
And bringing gain and wealth to mortal men.

This rhapsody, which repeats in gorgeous rhetoric the various steps of transmutation, seems somewhat overdrawn, yet Theophrastos in the use of exclamation is mild when compared with Stephanos, who in page after page of his prose treatise upon the sacred art lets flow a muddy stream of bombastic Greek. The science of the early Alexandrians had so far degenerated in the days of the Byzantines that it was made a theme for rhetoricians while the ancient clarity and conciseness, which made the scientific writings of Hippocrates and Archimedes models of expression, had now given way to deliberate obscurity of thought and to the empty jingling of an inflated style.

The alchemical poets conclude their verses with reflections of a moral and religious nature. This also was in general keeping with the custom of Stephanos and other Byzantine writers whose treatises usually began and ended with a prayer. Theophrastos simply followed the usage of his time and concluded his poem as follows:

Who, then, beholding the great universe
Which Thou hast wisely wrought,—a well-designed
Production, made with singleness of art,
And faith inspiring in its glorious works—
Entranced with wonder would not be amazed?
He would extoll the boundless providence
Of reason's God and praise the sympathy
Which He, in ways both wise and manifold,
To us declares. As Lord beneficent
He wishes all mankind a happy life
And wealth by their activities to gain.
Then let us shape life's course with reverence
And cherish piety's clear beacon light,
Our pathways brightening with godly deeds,
Our neighbor loving and the foreign guest;
And day and night with supplicating prayers
Our adoration pay, as servants wise,
To God the Lord, all-seeing King of all,

Forgiveness asking for our trespasses
And that all kin from danger may be spared
And from temptations freed, as they arise;
And let us never undertake a work
Unless we give the praise therefor to God,
The Father, who begot the only Son,
The Son, the holy Word from God produced,
The Holy Ghost, proceeding too from Him,
Both now and always evermore. Amen.

This ending in orthodox Greek fashion is typical and reflects in a measure the ecclesiastical mania of the times, which found its expression in liturgies, ceremonies and the other accompaniments of an extravagant ritual. The doctrine of the Procession of the Holy Ghost from the first person of the Trinity, contained in the next to the last line, shows that the poem was composed after the Council of Chalkedon in 451, and so could not have been written before this date as some have supposed. The same doctrine is promulgated in Stephanos to the disgust of Reinesius who, however much he admired the opinions of this writer on the subject of transmutation, could not uphold him in this.

The moral admonitions contained in Theophrastos and the other Greek alchemists were not, however, entirely the result of ecclesiastical influences. As the mystical doctrines of the alchemists gained ground the transmutation of the base metals into gold began to be regarded as a symbol of the transformation of man's own lower nature into something nobler and higher. The comparison of the nature of man with that of the metals was used, in fact, by Greek writers of the earlier Alexandrian period. Plotinos writes: "As gold is contaminated by the adherence of earthy dross, so is the soul corrupted by its union with the body." Hierocles makes a similar comparison in his commentary upon the Golden Verses of Pythagoras, where he says, "Gold is symbolic of virtue because it never corrodes while the baser metals gather rust which is typical of the vice that arises from material contaminations."

An example of the extension of this comparison, after the belief in transmutation had gained currency, is found in a fragment of so-called political verse, attributed to John of Damascus, who lived between 700 and 754. The poem, in which the lines occur, was called the Dioptra and gives a dialogue between the soul and body. The body mentions the unapproachableness of the state of man to that of God, but the soul in reply expresses the possibility of transforming man's condition by the following comparison:

It is as if when lead and gold are banished far asunder
A distance from each other's home, a distance wide are parted,
A certain craftsman then should come, who wished to show his cunning,
The operation of his art and scientific knowledge,
Should take this lead and melting it within his blazing furnace
Should show the same transformed to gold of quality the finest.
And this is surely wonderful and strange beyond believing
That what was never gold before, now gold becomes at present,
What was not gold has gold become, though not so at commencing.
O great display of excellence! O great display of reason!

The alchemists, who were always immoderate in their use of symbols, finally carried this comparison to its ultimate extreme with the result that the symbol became of paramount importance, while the act of material transmutation sank into insignificance. Stephanos, the chief Byzantine writer upon the sacred art, makes the following digression towards the close of his eighth praxis:—

> From the objects of sense perception pass over now to those sights which are perceived by the mind. Behold the great order and immaterial splendor of the heavenly bodies. When thou hast seen the beauty of these, lift up thy mind beyond and noting the resplendent glory and great joy of the angels do not hereafter be led astray with respect to the material transformation of this earthy substance, of that which is sought after by the hand and revealed by the philosophy of gold-making.

It is not surprising, therefore, that certain writers upon the subject should hold that all the old treatises upon alchemy are simply moral and religious allegories and that the gold, "such as was not found in the treasuries of kings," was of a heavenly, and not of an earthy, kind. An American writer, Ethan A. Hitchcock, was the first to advance this view in 1857 in an anonymous book of some three hundred pages. The same opinion in a modified form is also held by the well-known English writer, A. E. Waite, best known for his scholarly edition of Paracelsus.

The theory, however, that ancient alchemy was a moral allegory and nothing more carries with it its own refutation, for if we accept it as true we must also admit that there was a strong contemporary belief in the actuality of transmutation, otherwise the symbol and allegory would have had no meaning.

It was a strange reversal of ideas that the so-called sacred art, which originated in the fraudulent practises of Egyptian counterfeiters, should have afterwards developed into a means for the inculcation of virtue and religion.

THE ECONOMIC PROBLEM OF THE OZARK HIGHLAND

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THE term Ozark associates a group of regions possessed of widely divergent characteristics. Simplicity and similarity are hardly more representative of the Ozark areas than they are of the regions grouped together under the term Appalachian. In the Missouri Ozarks eight distinct divisions must be recognized, and for Arkansas at least two more are to be added. It becomes a matter of more than ordinary difficulty therefore to speak of conditions and problems in the Ozark Highland as a whole. Yet there must be an adequate geographic unity, otherwise popular usage, unbiased in this case by common political traditions, would not have set up this regional designation.[1]

(1) The Ozark areas constitute a compact highland, for the most part notably elevated above the adjacent areas. This is the common factor in the topography and for this reason no more precise term than highland can be employed appropriately in a geographic sense. In the interior the highland consists of a remnant plateau area, broken into long shreds by stream dissection. Except on the west, hill belts, of very difficult character, surround the central region. The outer flanks of the hill regions, with the exception of the southern and southeastern portions of the highland, are adjoined by less rough border areas of superior resources and development. (2) Even in the Ozark areas of least relief there is more rough land than in adjacent regions which usage does not place in the highland. (3) Ridges and valleys are sharply differentiated. The topography is dominantly of the ridge-and-valley type. (4) Most of the area has been sculptured out of limestone by streams with the abundant aid of underground solution. A close genetic relationship exists between the widely distributed sinks, caverns, springs, and the lead ore, iron ore, and other mineral

[1] The differentiating characteristics of the several parts of the highland and their economic effects are considered in detail in the volume by the author, "The Geography of the Ozark Highland of Missouri," published as Bulletin 7 of the Geographic Society of Chicago (1920).

deposits. (5) A significant property of the Ozarks is the almost universal distribution of chert fragments over the surface. These produce similar effects on slopes, soils, stream beds, and on agricultural practises and roadmaking. Such in the main are the common qualities that are opposed to the multitude of differentiating conditions.

In the following pages the attempt is made to determine whether there exists also a common economic problem for the area as a whole. The inquiry is concerned chiefly with the heart of the Ozarks, namely, with the central plateau and its surrounding hill areas. Just as popular usage is uncertain regarding the inclusion of the border areas in the highland, so the economic conditions of the borders are only in limited degree typical of the area as a whole and the generalizations that follow can be applied to such regions as the Springfield, Missouri River, and Mississippi River borders only with important reservations and exceptions.

The most common conception current regarding the economic character of the Ozark region is its inferiority to the regions that lie about it. The idea is substantially correct and may be demonstrated statistically in many ways by the values and amounts of crops and of other products which the area yields.[2] These facts appear to register the adjustment of a group to an inferior environment. This is true in part, but it does not fully account for the economic situation. There still remains to be considered the question whether the Ozarks are underdeveloped relative to such resources as are available under present economic conditions. In particular it is necessary to inquire whether the economic adjustment is to the present or to a previous value of the environment, for the environment is not necessarily a static factor uninfluenced by the passage of time and the changes in opportunities of production. The case to be examined concerns the possibility of an original adjustment which has since been revised insufficiently, with the result that the Ozark Highland has fallen behind seriously in the progress that may be expected of it, making all due allowances for thin soils, steep slopes and other handicaps.

When settlement west of the Mississippi River began, the flanks of the Ozarks were preferred to all other territory in upper Louisiana. This preference continued beyond the time when Missouri and Arkansas were admitted to statehood, and

[2] For illustrations see volume *op. cit.*

was based on the variety and balance of the local resources rather than on the large amount of any one resource. It was the possibility of sufficiency and especially of self-sufficiency that caused to be located in this area the first American settlements west of the Mississippi. When transportation facilities made commercial production possible in the West, farm immigration was diverted to other areas. The true pioneersman, however, not intent on producing a surplus of crops for sale, was able to occupy step by step the whole of the Ozarks, conscious of no deterioration of his environment as he penetrated into areas of longer and steeper hills. For was there not everywhere good hunting and fishing, excellent water, grazing for his horses and cattle, mast for the hogs, and patches of bottom land for corn, beans and pumpkins? Here he could meet his own needs of lead and gunpowder, dig his iron ore and smelt it, and have ample power for his grist and carding mills. Frontiersmen, rather than agriculturists, became the permanent occupants of the area. With the filling up of adjacent regions, the Ozarks became a sort of refuge to the men who clung to frontier life. After a fashion the frontier still lingers in the Ozarks, but the unconstructive character of frontier living and the increase of population have gradually caused the disappearance of some of the more agreeable features of this life. For an understanding of the area it is essential to keep in mind its antecedents, and also that the blood of the frontiersman is still dominant among the population.

At present, the Ozarks contain somewhat less than thirty per cent. of the population of Missouri, resident on approximately half the area of the state. Since a full third of the people of Missouri live in St. Louis and Kansas City, the population of the Ozarks is nearly of the same density as in the rest of rural Missouri. The situation in Arkansas is similar. Whereas immigrants have not been numerous, serious loss by emigration began later than in other near-by rural districts. Population had not increased to the limit for the food supply under the methods of production practised, and the world outside was little known. The last census, in 1910, was the first to record declining numbers over widespread areas. In the beginning of the new century, rural free delivery of mail became generally established and a serious blow was dealt thereby to the old isolation that had kept people at home. The effects of the late war probably will be even more far-reaching. In 1917 the government placarded the most remote

post-offices with calls for workers in war industries and offered the opportunity of rendering a service to the nation and of securing wages of a magnitude unheard of in this country where wages for the most part have been nominal. Large numbers left for the cities of Illinois and northern Missouri and for the mining and oil fields. The draft took thousands of young men away from home for the first time, and introduced them to new standards and modes of life. Many are not returning. The great prosperity that is continuing through the country has found only a weak echo in the hills of the Ozarks and additional workers are still leaving to share in the high wages outside. The past five years, therefore, have seen a critical increase in the emigration. The old contentment with the simple home in the hills was based in part on a lack of knowledge of outside conditions. A world catastrophe has supplied this knowledge. The selective elimination of the more ambitious of the younger generation is in full progress.

Under these circumstances attempts by railroad immigration officials and state bureaus to direct immigrants into the Ozarks are misplaced. If any effort is worth while it must be concerned with retaining the native population. Relative to developed resources the highland is more densely settled than its neighboring areas, and largely in consequence labor commands lower returns. Emigration is natural and inevitable as long as it is directed by economic pressure as at present. The better sons of the Ozarks can find it worth their while to remain only if defects in the present economic adjustment are found and remedied. If nothing of the sort happens, the drainage of this best blood will continue permanently and will express itself in the decreased productivity of the area. The movement is only in slight measure similar to the release of a portion of the population by improved methods of production such as has been the case with power farming in the prairie states. The emigration now in progress indicates the beginning of actual economic decline in numerous sections, if not yet generally.

It does not follow from the foregoing that the people of the Ozarks live in want. An initial period of no inferiority has been succeeded by a century in which contrasts with surrounding regions have grown sharper and less favorable. The consciousness of such an unfavorable comparison is in the main a matter of recent growth. The drifting away of the most productive part of the population is following naturally and constitutes a threat of increasing seriousness.

The half of Missouri that lies in the Ozarks possesses less than one sixth of the wealth of the state. In terms of population, however, the situation is much more favorable. Valuations returned by the State Board of Equalization for 1918 are approximately three hundred and twenty dollars per capita for the Ozarks, as against five hundred and seventy-five dollars for the entire state. In this calculation there are included in the Ozarks such prosperous centers as Springfield, Jefferson City and Cape Girardeau, as well as the mining regions of Joplin and the St. François district. On the other hand, the largest area of rough hill country in Missouri,[3] embracing a half dozen counties of extremely low total valuations, shows per capita valuations nearly equal to the average of the whole Ozark Highland. Two of the roughest counties in the Ozarks,[4] exceed the per capita average of the Ozarks by one eighth. The explanation is that in the rough hill areas the hills are almost entirely non-agricultural and the population is concentrated on reasonably good valley lands. Also, in a comparison of the Ozarks with the remainder of Missouri it must be remembered that St. Louis holds a full third of the wealth of the state, and that St. Louis and Kansas City together account for nearly one half of all property. According to per capita of population, the valuation of the Ozark region is easily two thirds that of the remainder of Missouri if the two principal cities are eliminated.[4] Certainly no general condition of poverty prevails.

If the region gives an impression of poverty to the casual visitor the explanation must be found in the simplicity of the habits of the people and in the even distribution of wealth. Few men possess much more than their neighbors, but want is not much more common than is wealth. There are a few poverty spots on submarginal farming lands, which are not in the supposedly poorest regions, the rough hill sections. Too much emphasis has been given to the idea of poverty in the Ozarks. The parallel between the living conditions of the Ozark native and the mountaineer of Kentucky and Tennessee is not at all close and even less so is that with the poor white of the southern Coast Plain. A degrading environment can be shown only for very limited tracts and these are for the most part outside of the cherty limestone regions. The trouble

[3] The Courtois Hills region of the volume, *op. cit.*

[4] Carter and Shannon counties.

[5] The figures are compiled from the Report of the State Auditor of Missouri for 1917–18.

lies in the stagnation of life, as expressed by the lack of development of new opportunities, and in part in an incipient contraction of standards of living because an outworn economic system is still followed.

The economic system has been altered only in minor ways from that which was in force at the time of early settlement. The average inhabitant of the Ozarks is still an unspecialized small farmer, rather than a farmer following an intelligent practise of diversification. Of labor income he knows nothing, and commonly has none. The pursuits which he follows give little opportunity for the accumulation of a surplus. The aim of labor is hardly commercial, the labor being expended directly toward the sustenance of the family. The condition is characteristic of primitive groups. The economy is based primarily on agriculture, but agriculture is typically only a partial means of subsistence.

Corn is the dominant crop. It is grown on thin uplands and on stony hillsides as predominantly as it is in rich bottoms. It is produced not only with almost total disregard of the character of farming land but of the size of yield as well, simply because it has a larger direct utility to the individual farmer than any other crop. It feeds the family, and the horses, cattle, and hogs. It will keep without means of storage. It will grow in the most poorly prepared ground. It yields the largest returns of food per acre cultivated. Also it was grown by the first settlers as the main crop and their descendants are following the old traditions. From the standpoint of commercial development, from every standpoint in fact, except that of a farm functioning as a self-sufficing unit, corn is grown very much in excess of the best interests of the region. Except in the bottoms, the land has been much too heavily "corned" for years and increasing difficulty is experienced in maintaining yields. But from the highly individualistic viewpoint of the native it is the most suitable crop for his social system or the lack of such a system.

In addition to being a corn-farmer, the resident of the interior Ozarks is normally a live-stock producer. He could not be designated, however, a rancher, breeder, or feeder. The form of the industry also goes back to first frontier, and was responsible in large measure for pioneer immigration into the Ozarks. The plateau shreds, even where they were only narrow ridge-tops, were covered originally with grasses. They are still commonly called prairies. On these live-stock grazing was instituted at an early date. Fires were set habitually by

the pioneers to replenish and extend the grazing lands. These fires extended the grass lands at the expense of the forests. Grazing itself extended into the forests as the population increased. Fires and long-continued grazing in the forests have interfered in many districts with the growth of seedlings, sprouts, and other undergrowth, and have resulted in a forest-floor covered with grass and weeds. The ridge-tops are now converted almost entirely to plow land, and grazing has therefore suffered a restriction to the forested areas, which are nearly equivalent to the hillsides. This poor, volunteer pasturage among the trees is incapable of improvement and by reason of long-continued grazing at all seasons has been steadily deteriorating. With the elimination of the natural grass lands the cattle industry has largely passed into the condition of a relict industry.

Hogs fare much better, being essentially forest animals, and finding here a varied and often good mast of acorns, nuts, berries, and roots. The razor-back animal is an unimproved, but successful adaptation to his peculiar environment. Sheep are very few, because, roaming at will, they are subject to serious danger from dogs, who are also unrestrained. Turkeys thrive under a similar life, in which they partially revert to an undomesticated condition.

The keeping of stock bears virtually no relation to the ownership of land. All land that is not farmed or in fenced pastures constitutes the free range. This consists in part of large timbered holdings belonging to absentee owners. Many large tracts are crossed by the property lines of local farmers but are not shut off by fences. The result is that stock ranges widely through the woods, for most of the year without attention. As a consequence the struggle for a bare existence keeps it in poor flesh. Even more serious is the reproduction by accidental breeding from scrub sires. Against the ease of this method of live-stock raising are to be set the very low quality of the product, the decreasing carrying power of the range, and the uncertainty of the returns.

The average farm contains more wooded land than it does cleared land. This is true even of the border regions, with the exception of the Springfield area. In the hill counties there are likely to be three or four acres of timbered land for every acre cleared, in each farm. In addition there are large timber tracts that are not included in farms. Timber products therefore are an important item in the economy of the native. These items are produced and marketed principally by the

farming population, not by lumbermen. The principal products are ties, and in some localities, cord wood and mine props. The important stands of white and post oak are especially valuable for ties, of which the aggregate production is large. The principal winter occupation is the cutting and hewing of ties. They are then hauled out over the frozen roads, or later rafted downstream during freshets. The industry is pursued with particular zeal because, among a group of part-time occupations that yield little for sale, it provides cash returns. The very great increase in the price of ties has lately stimulated strongly the search for suitable tie timber. There are few sections in which the trees available for this purpose are not fast decreasing, and the cutting of such timber has proceeded into the most remote localities.

Numerous minor and incidental occupations are followed also for their cash returns or for purposes of barter at the country stores. Here belong the digging of roots such as ginseng, golden seal, and blood root, hunting and trapping for skins, and the digging of minor minerals, such as tiff (baryte) and fire clay. In most cases, increased prices have made good a decreasing supply, but the supply of these auxiliary resources is in general markedly declining.

The Ozark farmer in short is following a system of production that is in reality simply exploitation. In virtually all of his occupations he has passed the period of largest volume returns, although aggregate values may still be mounting. Increased prices can not permanently resist the actual decline that is threatening the productive efficiency of the individual. Exploitation is a mark of the frontier and the perpetuation of the frontier is recorded strikingly in this general condition.

The reasons for this peculiar fixation of a frontier are not difficult to determine. In the first place, to a degree not equaled elsewhere in the Middle West, the people of the Ozarks are descended from frontiersmen. The parent stock represents a certain aversion to orderly and sustained endeavor and therefore to intensive production. To what extent the trait persists as a hereditary quality is not known, but, given the opportunity, the native of the Ozarks apears to be about as frequently successful as most other Missourians or Arkansans. The difficulty with his ancestry seems to lie not so much with physical inheritance as with the traditions among which he is brought up. At the least, he has not inherited the agricultural experience and interests with which his neighbors of the plains are surrounded. He goes back to a more primitive ancestry.

The biggest element in the retardation of Ozark life is the isolation that the surface has imposed on the inhabitants. A chain of rugged hill regions is thrown about the interior plateau and constitutes a veritable entanglement of obstacles against any approach from the lines of communications that follow the Missouri, Mississippi, and Arkansas rivers. Even more significant than the exclusion of the outside world is the detached manner of living of the people. Valley is separated from valley; valley settlement is out of touch with ridge settlement; often family is isolated from family.

The simple result is that the isolation has kept social and economic progress at a snail's pace. The people were primitive in their condition when they came, they are nearly as primitive now. Without strong social instincts and training to begin with, how were they to achieve common interests, common opinion, and common effort? For the economic problem of the Ozark Highland is after all social in its fundamentals. The difficulty that the people experience in getting to market is less serious than their failure to get together. There has been no substantial economic development because topographic isolation has maintained successfully the social anarchy of the frontier. It is the solitary position of the individual, rather than the poverty of the soil, that at bottom is at fault with the Ozarks. The so-called political conservatism of the Ozarks is well known. It has its full social and economic equivalents. The individualism is almost static. The individual produced under this system is bound down by it. How can he be intelligent enough or sufficiently strong to reshape the outworn economic order? There are adequate possibilities for the inhabitants of the Ozarks, but these can be realized only by fairly advanced cooperative effort. Of cooperation the native knows nothing beyond the relief of a neighbor in trouble. The stakes of the region are not such as to tempt extraneous capital and the social order therefore has received no alteration from the outside. Unless the region is to become decadent, the isolation and its resultant excessive individualism must be broken down, and this must be done by the governments among which the highland is divided.

The first corrective measure must be improved means of communication. The construction of additional railroad lines on the long shreds of plateaus is a simple matter. However, their returns for a considerable period would hardly be sufficient to tempt private capital. Unfortunately also several Ozark branch lines have been abandoned lately. Similar expe-

riences in other sections of the country indicate that the time is probably past for the construction of branch line railroads.

The main wagon roads follow ridge tops. Their location is determined by low cost, freedom from floods, and freedom from erosion. They are passable throughout the year, but serve directly only the settlements on the ridges. Over large sections these settlements are not as flourishing nor as promising for future developments as the valley settlements. It is notorious that the traveler on the main roads sees very little of the better land. The ridge roads are separated from the valley farms by steep hills. Connection between the two is made by rough and often badly washed side roads. The secondary roads that follow the valleys are subject to flooding with every freshet and are often washed out. Fords are innumerable, bridges few. The location of roads was determined by the easiest lines of travel. The adjustment is complete so far as it goes, but it is based on unimproved roads that are simply traces worn by travel. Permanent roads are needed in the valleys. Their appropriate position would be on the lower flanks of valley slopes out of reach of floods. Roads of this type can be had only by moderately costly construction.

The road situation is so bad that it is almost impossible, and consequently a number of counties are now undertaking road building by bond issues. The present policy of state aid is contributing important funds indirectly from the wealthier portions to those Ozark districts that desire to avail themselves of help. There is an unfortunate tendency, however, to follow the locations of roads as they have become fixed by pioneer custom and to superimpose the improved road on the all-weather trail. In the building of roads there is needed not merely the technical skill of the road engineer, but a close economic analysis of the distribution of good farming districts and their relation to road facilities.

The live-stock industry as a cooperative enterprise, in place of its present individualistic form, is indicated as the dominant ideal occupation of the future. (1) Partly as the result of the long period of erosion, partly because of the powerful aid of solution, valley bottoms are extraordinarily numerous and large, even among the roughest hills. Their rich soils, annually reinvigorated by floods, are suited to continuous cropping to corn. The only argument for rotation of crops on these lands is the elimination of diseases of the corn plant that may find lodgment in the ground. On the valley lands, soy beans, velvet beans, cow peas, clover, and alfalfa also grow very well. These

lands may grow important quantities of high-grade stock feed. (2) Cheap grazing lands are available in large amount. The lower valley slopes, the slip-off slopes of intrenched meanders, benches on the sides of valleys, and the smaller ridge-tops especially are well suited for hay and pasture. Many ridge lands are being cropped that should not be under plow. Their thin clay soils are unprofitable for grain growing, but will produce good grass, as they once did. In connection with a really profitable live stock industry these ridge lands would be employed most profitably as permanent grass lands. At present the most indigent larger group of farmers in the Ozarks is found on ridges of this type. Very valuable forage grasses and clovers are in process of naturalizing themselves successfully, and with some protection will improve the quality of the forage markedly.[6] It is to be remembered that the strikingly poor quality of present pastures is the result of over-grazing and utter lack of care. (3) The mild climate and abundant rainfall extend the grazing season almost to nine months. Woods, cliffs, and coves provide partial winter shelters, too often the only ones supplied for the stock. Housing and winter feeding, however, are not serious problems. (4) Probably no other section of the United States is so well supplied with springs. Throughout the limestone country magnificent springs of cold and pure water abound along all valleys. The assertion is often made by a farmer that he has a good spring in each pasture.

Cattle, hogs, and sheep all have their place on the Ozark farm. (1) The first step in improvement of conditions is also the easiest. It consists in the elimination of undesirable sires. Even this is a community enterprise, both as to the purchase of pure-bred males and the disposal of the undesirable males. The custom of allowing stock to range about in the forests is not likely to disappear soon, nor is it necessary if the control mentioned is exercised. (2) The Ozarks constitute potentially a great dairy country, undeveloped at present except for certain border regions. The absence of dairying is due to the serious difficulties in marketing and the utter lack of experience of the people. Cheese making is largely independent of shipping facilities and could be undertaken even in remote valleys. A geographical parallel is to be found in the Carolina mountains, the physical conditions being somewhat better in the Ozarks. In remote Carolina valleys a remarkable success has been scored in the past few years by cooperative cheese fac-

[6] Lespedeza, sweet clover, blue grass, and Bermuda grass.

tories. The conditions of living in many an Ozark valley could be transformed similarly under proper direction. (3) A successful swine husbandry could be worked out by combining farm crops with mast and introducing a suitable breed, as for instance one of the forest-bred English varieties of bacon hogs. No attention is being given to the preservation and increase of the kinds of trees that are most productive of mast, for exploitation does not heed any demand except that of an immediate profit, even if small.

For every acre in the Ozark that is in any way improved there remain two acres in the woods. In that third which is classed as improved land is included a good deal of rough, stumpy pasturage with a partial stand of timber remaining. In the hill regions the amount of improved land is very small. It is least in Carter County, with only nine per cent. of its total surface improved. The wild land for the most part is covered with oak timber, cut over repeatedly. The majority of the timber to-day is small, and where grazing has not been heavy the second-growth is dense. Potentially, it is one of the two most important stands of oak timber in the United States. The removal of the older trees and the neglect and injury of the second-growth are resulting in rapid deterioration. In many places even the acorn mast has been destroyed by the cutting of seed-trees. Grazing has done much injury to the forest floor, with the result that the growth is less vigorous than climate and soil would indicate. The good timber is nearly gone, but the land on which it grows is essentially non-agricultural. Little of it has been laid waste by fires. It is probably no exaggeration to estimate that fully half of the Ozarks can never be good for anything except the growth of trees. It is not growing good trees now and soon will be virtually non-productive. Missouri is facing the idleness of a fourth of its total area without so much as a forestry office in the state to take notice of the situation. Arkansas is in no better condition. The problem of restoring these forests to a productive condition must be worked out in cooperation with the farmers who own a good half of the forest land and who will continue to be dependent in various important ways on forest products.

As yet there has been surprisingly little soil destruction in the Ozarks. Many Ozark streams are quite clear, even in flood. Gradually land clearing is pushing into the margins of the 'breaks' with no profit to the farmer and with the threat of grave damage to the countryside. These dangerous clearings for the most part are made by ridge farmers who need addi-

tional acreage and are taking a chance on the upper slopes of the valleys. The clean cutting of timber, fortunately, has not been much practised, as it is of no advantage to the farmer. Land clearing has nearly reached the limit of safety, and will shortly pass it unless the economy of the area is readjusted. The states concerned are still in good season for the introduction of land policy that will save the forests and their water power, protect farming development, and relieve the taxpayers from the burden of supporting large areas of idle lands.

Roads, live stock and a forest policy point the solution to the stagnation of Ozark life. There will be other forms of development, which even now are under way, but these three are the fundamentals. Water power will be developed in increasing amounts, but its benefits will go primarily to the cities that are situated about the Ozarks. Tourists will discover increasingly the merits of a recreation in Ozark streams, but it is to be hoped that the native will not have his simple hospitality spoiled by summer visitors. Fruit growing has received much publicity and there are a number of good, established fruit districts. Elsewhere, shipping facilities and organization present difficult problems. Thin soils and steep slopes are antagonistic to permanent orcharding. Missouri possesses in her loess lands a much more productive fruit soil, much better located than the interior Ozarks, and developed for orcharding to only a very small extent. It would probably be beneficial to the development of the Ozarks to place relatively less emphasis on the possibilities of fruit.

Help is needed for the Ozarks. The condition of the people is such that they can not well help themselves. They are standing singly, uninstructed in their larger possibilities. It is a numerous population that needs to be made more effective, before degenerative selection destroys its best capacities. State investigators here and there are carrying on inquiries into Ozark problems, but the work is largely lost because advice is given in the main to those who know how to call for it. What is needed above all is a policy of development for the region as a whole which will recognize the unity of the problem, not its fragments. If the states involved have the patience and the wit to plant the community spirit in the valleys and on the ridges of the Ozarks, the native will find in himself and in his environment the resources with which to develop a permanent constructive economy in place of the present self-destructive system handed down from frontier ancestors.

GIANT SUNS[1]

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THE new secrets wrested from the stars have chiefly come, not from the increase in size of telescopes, but from the new appliances attached to them, such as the photographic plate, the spectroscope, and by this time many others. The lines in the spectra of stars tell us what the stars are made of, how they may be classified accordingly, how fast they are moving, how bright they really are (this is an amazing recent discovery), and by inference how far away, and may yet have other surprises in store. For the moment we are chiefly concerned with the classification. The Harvard system gives us a number of classes denoted by the capital letters O B A F G K M R N. The fact that the order is not quite the same as that of the alphabet represents a revision of early ideas, chiefly due to the gradual accumulation of intermediate types, which make a nearly continuous series.

Now a series of stars in order is probably a representation of growth; just as the growth of trees may be illustrated by selecting various stages from the same wood, an illustration originally given by Sir W. Herschel. But we have seen a tree grow, and we know independently that it grows up from the acorn through the sapling to the giant oak; while we have not had time to see a star grow and were thus in ignorance whether the changes are from B towards M or from M towards B, though by this time we have an immense number classified. The classification has been largely the work of an American lady, Miss Cannon. I am told that there is a man who can deftly straighten rifle barrels—he gives a glance along the barrel, a tap with a hammer, and lo! it is straight. His value is recognized at some £15 a week. Miss Cannon has the same deftness with spectra—but I fear that (to judge from the report of the Board of Visitors of Harvard Observatory) her great skill is not so appropriately rewarded.

Now it is obviously important to find out, if we can, which is the direction of a star's growth, and we seemed to have an im-

[1] From an address before the Royal Institution of Great Britain.

portant clue when the spectral classification was connected with the temperature of a star, or rather its *surface* temperature, which is all we can get at. The outside is the coolest, just as the edges of a plate of porridge are the coolest, as most of us have learned by early and rather painful experience. And yet the outside of a star is hot enough. The temperature is again estimated from the spectrum, though this time not from the lines but from the relative intensities of the ends, and the O B A end is undoubtedly hotter than the other. We may give as illustrations 15,000° for B, 5,000° for G, and 2,500° for M. Does this settle the matter? We know that there is a general tendency for all bodies to cool which points to the direction C B—M N as the order of events; but it was also known that under the stress of gravitation a star might rise in temperature, in which case the growth might be the other way. Still the former alternative commended itself more generally; and when Professor W. W. Campbell found that the velocities of stars (also determined with the spectroscope) were smaller for type B than the type M, the facts were interpreted to mean that a star moved more quickly with advancing age (because M stars were older than B). The idea that the life of a star was spent in passage down the series O B—M was indeed pretty firmly established at the time when the revolution came.

The revolution began with the advent of a young American research student, Mr. H. N. Russell, to Cambridge in 1904–6. It is to the credit of Mr. A. R. Hinks that he made so much of this brilliant young student, setting him on the way to determine the distances of a number of stars by photography with the instruments which he (Mr. Hinks) has spent much time and labor in perfecting. This was the first element in his success. The next was that on his return to America he got from the Harvard Observatory—that storehouse of astronomical facts—the spectral types of his stars; and combining these with the measures of distance (which told him the intrinsic brightness or luminosities of the stars) he found that stars of the same spectral type M fell into two distinct groups separated by an interval. There were very bright stars, now called Giants, and there were very faint ones, now called Dwarfs, but none of intermediate stature.

The same was true in minor degree for stars of other types, but as the B end of the series was approached the gap gradually disappeared much in the way that the gap between the legs of a stepladder gradually lessens as we approach the top. Indeed Russell's diagram of his results is very like a stepladder, the top representing the B stars followed by A, F, G, K, M, in

descending order, and the gap between the two legs of the ladder representing the difference in luminosity, as the intrinsic brightness of a star has come to be called. Russell brought this diagram with him when he came to attend the meeting of the Solar Union at Bonn in 1913. It is sad to remember the occasion, for the most friendly relations seemed to have been permanently established between the various nations assembled. We remember with especial regret the trip on a great steamer on the Rhine which ended the meeting, and, alas! was the end also of our hopes of a permanent friendliness, for before the year had passed the Great War had shattered them all. It was on his return from Germany through England that Russell showed us his stepladder diagram at the Royal Astronomical Society, and expounded his views on the evolution of a star, which were that its life began at the foot of the upright leg, the ascent of which signified that the star was growing continually hotter and changing its spectral type meantime from M upwards towards B, that at B the increase of temperature was arrested and after a time cooling began carrying the star down the inclined leg of the ladder through changes in the reverse order. The only weak spot in the evidence arose from the small number of observations. To determine the actual or intrinsic brightness of a star we must know its distance, and there are not many stars of which the distance can be easily measured, and though Russell had himself increased the number, the total was still not large. To get further evidence he had recourse to indirect estimates of distance, especially those of clusters of stars. We have lately become more and more aware of the association of stars in clusters represented by their common movement, somewhat in the way that the movements of a flock of birds migrating from one place to another are associated. If we may accept this evidence, and if we can determine the distance of any one star in the cluster, the distances of the others can be inferred. In Russell's skilful hands this evidence was collated and found to strengthen his conclusions.

Let us pause here for a moment to reflect on the inherent probability of the suggestion. Is it not after all much more likely that a star first rises in temperature and then falls rather than that it should be permanently either rising and falling? Now that the idea has been put forward, and that there seems to be not only good evidence of this change in the sky, but, as we shall presently see, also good theoretical reason for it, we wonder why the idea was not the most natural one to adopt from the first. But curiously enough it was not the one adopted by astronomers, with the notable exception of Sir Norman Lock-

yer, who made the same suggestion as Russell's (though on different grounds) many years before. May I give a crude illustration from our ordinary life of the mistake that was made by many of us? It is as though we had taken the amount of hair as an indication of the age of a man. In very early life the amount of hair is small, it increases with age up to a certain point, but then it begins to decrease until a very old man often has as little hair as a newborn baby. We could give Shakespeare's Seven Ages of Man according to the amount of hair in the same diagrammatic form as Russell's stepladder, beginning with the baby at the foot of the upright leg, ascending to the man in middle life with maximum hair (corresponding to the maximum temperature), and placing the greater ages down the inclined leg till we arrive again at a bald pate. Shakespeare reminds us with his phrase about the voice "turning again toward a childish treble" that not only the hair but the voice goes through changes which show a reversal after middle life. We were practically confusing the baby stars with the old man stars until Russell called our attention to the fact; and now it seems quite easy to make the distinction. But there was some hesitation before the new views were accepted at all, chiefly on account of the lack of sufficient measures of distance, which left room for doubt. Recently the evidence has been reinforced in a remarkable way by a totally new and unexpected method for inferring the distances of stars, due to Mr. W. S. Adams, of the Mount Wilson Observatory in California. His discovery is that if we have two stars, one of which is very bright intrinsically and the other faint, but both of the same spectral type, we can find two lines of the spectra which have different relative intensities: let us call them A and B. In the bright star A is more intense than B, in the faint star B will be more intense than A. Now observe that this difference will persist however far we may remove the stars from us. By altering the distances we may make the brighter star *appear* the fainter, but we can pierce its disguise by noting simply that the line A in the spectra is the more intense, so that if the star *appears* faint we see at once that this must be due to its greater distance. In fact we can infer the distance from the relative intensities of the lines A and B, so that Adams has really given us a new method of inferring distances. The new method has the further advantage of requiring far less labor than the old method of parallax; in fact, when once the spectrum has been photographed the further labor required is quite small, so that by this time Adams has been able to give us the luminosity of hundreds of new stars, and by this overwhelming evidence confirms Russell's results derived from merely a few.

In addition to this confirmation by new observations we have had an independent confirmation by the brilliant theoretical work of Professor Eddington, who has attacked the problem of the life of a star mathematically. He supposed a mass of gas first of all to be simply under the action of its own gravity. It will consequently contract, and owing to the contraction will rise in temperature; but Professor Eddington soon found that this simple hypothesis would not answer—it led him to impossible results. Clearly something else beside gravity must be at work, and he was driven to the further hypothesis that the *radiation-pressure* inside the star played an important part in its history. Radiation-pressure (or if we like to call it so, light-pressure) is what makes the tail of a comet. As a comet approaches the sun it begins to feel the effects of the fierce light, which is known to be able to drive away very small particles from the head of the comet, much as we can blow away chaff from wheat. In consequence of this action the small dust-like particles which may exist in the head are believed to be driven outwards to form the tail. But this force is not merely in existence on the outside of the sun, it permeates its whole body. A particle inside the sun is of course receiving radiation-pressure from all its surroundings, but the pressure will naturally be greater on the hotter side, *i. e.*, on the side of the sun's center. Working out the problem afresh with the addition of this new factor, Professor Eddington has obtained results which agree satisfactorily with the observed effects, and indeed the closeness of the agreement is startling. He is able to utilize the fact noticed earlier in the acticle, that the masses of the stars are not very different, so that it is easy to take three representative cases—let us say one in which the mass is equal to that on our sun, one in which it is 5 times greater, and one in which it is 5 times less—and by following these three cases in detail he can show the distinctive features of different stars. Briefly, the stepladder is highest for the star of greatest mass, which may get hotter and hotter until it reaches type O; a star of intermediate mass like our sun is arrested at a lower height, and may not reach higher than type F, or at best A, before it begins to fall down the inclined leg; while a star of small mass may reach no higher than type K at any time. The golfers in the audience may be reminded of their handicaps. Those who are destined to be scratch players (probably, however, *not* because of their great mass) improve very rapidly until they reach the highest pitch of excellence, and it may even be only in old age that they begin to travel downwards; but then there are others of long handicap, who although they may improve a

little at first never get beyond the fatal 18 at their best, and on whom declining years soon begin to leave their mark.

One of the most remarkable suggestions of Professor Eddington's work gives a reason for the close resemblance in mass of the stars. There is a certain mass for which the radiation-pressure pressing outwards nearly balances the force of gravitation pulling inwards, and it is clear that for stars as large or larger than this a break-up sooner or later is to be expected. This assigns very obviously the upper limit to the masses—we can easily see why there are no stars larger than a certain limit. But how about the lower limit? Are there no stars *very* much smaller than this? Certainly there are: we are living on one of them. Our earth is smaller by some thousands of times; but then it is not a star in the full sense, for it is not shining with its own light. If it did ever so shine the light must have been feeble at best and have only lasted for a very short time. There may in fact be many small stars, but *we do not see them,* and accordingly have not reckoned them in saying that the masses of the stars are closely similar.[2]

I can not give you a better idea of the value of Professor Eddington's work than by quoting a few words from a letter written to me by Mr. Russell, again specially in response to a request mentioning this lecture: "What appeals to me as the big thing is Eddington's work on radiative equilibrium (MN 77, p. 16 and p. 596). The importance of this can hardly be exaggerated; it is not too much to say that it is the first rational theory of stellar constitution."

Eddington has in fact given us a rough attempt at tracing the history of a star of given mass. By way of illustration let us consider our own sun. He is now a "dwarf star," on the descending leg of the ladder, of spectral type G, and with a surface temperature of about 5,000° C., and an absolute magnitude 5.1. Looking back into the past he was at one time much hotter and of type F, and probably never rose much higher than this on the ladder. Before that his history lay on the ascending leg, and there was a time when his spectral type was just as at present, but his absolute magnitude was near zero, five magnitudes greater than at present. This means that the total light was 100 times greater than now, and since the surface was in a similar radiative state, it must have been 100 times more extensive. The diameter of the sun was therefore ten times the present diameter—ten million miles instead of one million.

[2] On reading this again I realize that it does not do full justice to Eddington's suggestion for the lower limit. He shows a definite difficulty in the formation of small stars.

Where our little earth may have been at that time we can scarcely conjecture, but supposing for a moment that we had been able to regard the sun in our present conditions, he would have taken nearly an hour to rise instead of a few minutes; and when risen, his disc would be ten times as great in all directions—a "giant" sun indeed! And yet this magnification of 10 to 1 is only modest compared with the extreme possibilities.

We set out by the recollection of Jack the Giant Killer, but our road has led us rather to think perhaps of Jack and the Beanstalk. We have climbed up to Giant Land, the land of the giant suns, not by a beanstalk, but by means of the trembling rays of light, a ladder which does not grow upwards from our earth, but is let down to it by the giants themselves. "Fee Fo Fum!" said the Giant, "I smell the blood of an Englishman." In our analogy the giants have been invaded, not by an Englishman, but chiefly by an American; but at any rate we have the satisfaction of reflecting that his work began in Cambridge when he was a student, and that at the end of it there has emanated from Cambridge this brilliant confirmation by Professor Eddington of which the discoverer has himself expressed such generous appreciation.

THE MEDICAL AND ALLIED PROFESSIONS AS A STATE SERVICE

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ALTHOUGH preventive medicine is state-controlled, curative medicine is still the same unorganized, happy-go-lucky competition it ever was. Some thinkers assert that the time has now come for the applied science of curative medicine to be taken over by the state and organized into a system. Both departments—preventive medicine and curative medicine—would naturally be under the Department of the Minister of Health. Of course, there would be but one portal of entrance with one uniform standard of examination into the departments of curative state medicine and of preventive state medicine. This one standard of entrance would remove many existing anomalies. The doctor would then be to the whole public what the club doctor is now to a section of it. He would attend to the cure of cases exactly as the department attends to the prevention of cases. He would be a state official, salaried and pensioned as such. It is an anomaly that if your child has scarlet fever, while one aspect of the case can be properly taken in hand by an official only of the one aspect of medical science, the other aspect of the case has to be left to private medical enterprise. I should be able to summon a state-paid physician for a case of broken leg, pneumonia or insanity just as I now am able to do in a case of measles or diphtheria. This would, of course, lead to the whole problem of medical treatment being solved by being state-controlled. The great hospitals with their vast, beneficent out-patient departments would become state institutions just as prisons, penitentiaries and asylums are already.

There is no valid, other than a historical, reason why the scientific cure of disease should not be a state service as much as the scientific prevention of disease. The Indian Medical Service affords us an example of a state-managed medical service; it shows us how such an organization might be so vastly extended as to become imperial. Promotions, disability pensions, retiring pensions, etc., would be arranged for as in the Civil Service. The state would, therefore, also logically

take care of the problem of research in medicine, and, directing it, coordinate the isolated efforts made in it in the manner most beneficial to the public weal. In the United States, private enterprise has endowed medical research in a truly magnificent manner. Private endowments could still be given for medical research within the British Empire, but it would be well if the directing of medical research were made a responsibility of the state. Much of it is even now, as for instance, the splendid work on plague done in India, and the work on cancer in London. The medical researcher is a medical man no less than the general practitioner; he is only more specialized; he should equally be a servant of the state.

In an article by Colonel J. T. K. Maurice, C.M.G., entitled "A Vision of State Medical Science," which was published in *The Hospital* for November 9 and 16, 1918, the matter is put thus:

> Let us say in sickness the best advice and treatment is to be placed within the reach of every man, woman and child of the community . . . thoroughly efficient measures to ensure the good health of the community are to be devised and properly carried out. . . . Surgical and medical knowledge have stridden forwards so rapidly in the last few decades that the means of diagnosis and treatment to the hands of the medical profession are far more elaborate, far more efficacious and far more costly than they were heretofore. The guesswork of the old clinical diagnosis can be supplemented by X-rays, chemical tests, sera diagnoses and so forth, and an accuracy, a certainty, attained that was formerly impossible. . . . These elaborate processes are expensive, many require special buildings, costly apparatus, and men of long experience and special skill to apply them; and so under present circumstances they can not always be brought to the service of the sick. . . . Sera and vaccines, new powerful drugs, anesthetics, and antiseptic surgery, have brought about a wonderful change. But treatment by these means is an expensive matter, and entails the employment of highly skilled nurses . . . so the wages of nurses have risen and rightly. . . . The total result of all these changes is that the expense of making an accurate and fully confirmed diagnosis and of giving thoroughly sound treatment and nursing is so high that it is unattainable to most of the population except by charity. It could, however, be obtained by cooperation and mutual assurance, either by voluntary association or by submission to the necessary taxation. Either is better than the pauperization that comes of charity. The ideal is a healthy race, each man paying for himself or paying his share of the cost of maintaining the common health.
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> Sanitary science in all its wide ramifications has not yet come into its own. . . . In some large towns a good deal is done to preserve health by preventing disease. But the important step of thoroughly educating the mass of population has not yet been taken. All must learn that a healthy race implies parents without inheritable defects, strong and healthy in body and mind by gift of birth, implies restraint of the passions, avoidance of venereal disease, proper selection of foods, exercise

in fresh air, avoidance of overcrowding, good ventilation of houses, healthy occupation, healthy amusements, and happy occupation of leisure instead of unwholesome pleasure. One of the first needs of health is to learn wisely to use leisure. All this must be taught. A state medical service should be an educating service. If a state medical service were formed, its functions should be executive and advisory. It should carry out measures to prevent disease, but the measures would emanate from legislative bodies. It should advise parliament, county councils, corporations and other public bodies. It should suggest legislation. It should treat the sick. It should educate the community in the ways of healthy living, and it should administer itself.

Before we descend to the details of the working scheme of the state medical service, let us consider the exact point we have reached in what might be called the evolution of the medical profession from the individualism of the physician of the middle ages to the somewhat socialistic position which he occupies to-day.

If we go far enough back we find the doctor to be physician, surgeon, anatomist, botanist, zoologist and pharmacist, all in one. In the eighteenth century one single professor often taught botany, anatomy, surgery—and what physiology there was. But now he has evolved or been differentiated into at least six persons—anatomist, botanist, surgeon, pharmacist, pharmacologist and physiologist. Just as in the village the same shop is post-office, grocer's, tobacconist's and various other things all in one, in the great city it is represented by half a dozen distinct establishments.

There is another feature of modern civilization, especially in Christian countries, namely, the rapidly growing solicitude for the health and welfare of *sections* of the community as distinguished from the individuals in it. Previously, the individual physician treated or cared for the individual patient, and there his activities ended; to-day the public conscience is occupied with problems about the welfare of *group* or *sections* of the public; with soldiers and sailors as such, boys under fourteen as such; with those infected with venereal disease or with phthisis or those who are in prison or are destitute. Specific groups in modern society are being studied, examined, educated, treated and cared for generally in such a way as to show that the question, "Am I my brother's keeper?" has been very fully answered in the affirmative. Thus we have societies for ameliorating the vital conditions of Thames bargemen, policemen, postal officials, illiterate immigrants, ex-convicts, seamstresses, indigent gentlewomen, and many other groups in the community as such.

It is the day of a sanitarily minded humanitarianism; the cruelty of the eighteenth century—of the Hogarth pictures, for instance—has gone, we hope, for ever. Society with a big S used on Sundays to make up parties to be entertained by the howls and antics of maniacs chained behind the bars of cells in Bedlam, as the Hospital of St. Mary of Bethlehem was called. The eighteenth century was cold, artificial, antipathetic and cruel, but Hales and Howard and Elizabeth Fry and Florence Nightingale became pioneers in that movement towards modern sympathy not so much with the distress of individuals as with the sufferings of social groups.

At the present time it is the health of *sections* of the community that is the concern of governments: for instance, the health of miners and of workers in potteries and of wool-sorters, as such. We have become communistic, institutionalistic, socialistic, in the very best sense of that word. The instituting of a state medical service is entirely in harmony with the general trend of this ever-widening humanitarianism, for it means that the health of the nation is to be looked after in a manner similar to that according to which any other national concern is managed—war, the law, trade, agriculture or fisheries. We have officers and ministers for these affairs of national importance: it is suggested that we have one for the national health, a concern undoubtedly more important than any other.

The great war has made it very clear to us that far larger numbers of the population are physically infirm than we had any idea of. Even if all the military rejections were not sustained on revision, the number of men under the normal in health is alarmingly large. Now all this ill-health means inefficiency not only from a military point of view, but from every other. But the war, happily, has shown us something else, namely, that the applied science of national state medicine or hygiene could, by the working of a well thought-out organization, prevent the outbreak of those very diseases which in all previous campaigns proved more disastrous than wounds or bullets. In illustration of this, the following figures may be quoted: In the South African War the ratio per cent. of those dying of disease to those dying of wounds was as 65 to 35. In the Great War the same ratio was 5.14 to 94.85. This revelation is a great triumph for preventive medicine; it shows what, given a fair chance, it could achieve under the most disadvantageous circumstances. If all this prevention of disease

and this conserving of human life could be carried out under the most distracting conditions of the most inhuman war in the history of this planet, what could not state medicine achieve when working under the sane conditions of that normality called "peace"?

A national weakness must be met by national strength; a national disease by a national remedy. What were, then, briefly the factors that made for hygienic success in the war? First, expert knowledge and the services of relatively few experts organized for the benefit of relatively many people. This is precisely the principle we advocate being applied on an imperial scale. The war was won by cooperation, and the more speedily as that cooperation was the more perfect. Why should this principle not be applied under peace conditions? If fighting and the law are considered such honorable state services, why may the equally noble profession of medicine not be so considered? Surely fighting and destroying are not the only outlets for patriotism. I submit that it is as patriotic to save the lives of the children of a state as it is to take away those of its enemies. It does not invariably require great skill, though it may require great courage, to take away a life; it sometimes requires all the resources of science to save one. As an old friend of mine used to say: "Any fool can burn my shirt; what I want is some one who can iron it." While the highest expression of the patriotism of a day that is dead was to be proficient in the art of destroying life, may we not hope that the highest form of the patriotism of the day that has just dawned may be the attaining to the highest proficiency in the science of preserving life?

This state medical service is something more than merely organizing the medical profession as it exists at the present moment; it is nothing less than the creation of a state service for the explicit purpose of maintaining the highest health of the highest number of the citizens of our empire, and therefore systematically preventing the outbreak of diseases amongst them. This new service would conserve the health of all our social groups; the navy, army, the merchant marine, civil servants, inmates of prisons, penitentiaries and asylums for the insane, boys in reformatories, defective children, the blind and deaf and dumb, immigrants and all foundlings. This state service would so supervise the health of school children that all our present amateur efforts towards child-welfare would become superfluous. It would take charge of all hospitals, general, surgical, maternity, for venereal diseases, for cancer and

incurable diseases, and, of course, of all sanatoria, for all such institutions would then belong to the state. The service would supervise the noble nursing profession in all its activities. It would investigate all problems coming under public sanitation—adulteration of food, the storing, cleansing and distribution of water, inspection of ventilation, quarantine, prophylactic inoculation, and everything else included under "State Medicine" in the older, more restricted acceptation of that term. It would supervise all specialisms and techniques, including dental surgery, orthodiascopy and the therapeutic use of all forms of energy. Naturally, the compilation of vital statistics would fall under the province of the service. Finally, it would not only organize, direct and reward research, but also organize direct and reward all forms of teaching required in the medical profession; for by the time of which I am speaking, the universities, like the hospitals and laboratories, would have become state institutions. There would not only be no private hospitals, there would be no private schools of the cause and treatment of rheumatoid arthritis and other medicine whatsoever. Research into such large problems as widespread diseases responsible for a large measure of national inefficiency and suffering, could at last become a national affair and be investigated on an adequate scale.

This is neo-socialism, socialism in excelsis, which has absolutely nothing to do with the socialism of the red tie and the levelling down to an h-less vulgarity. Therefore, for this neo-socialism a name is needed; I would suggest *cooperationism:* for we are thinking not of any ideal and, indeed, wholly Utopian conditions where all men are considered equal (which they never were nor can be), but of a social state in which the special attainments of the cooperating few are specifically organized for the benefit of the many. Individualism, often heroic beyond all description, was sufficient for the earlier, ruder, simpler and smaller communities; but cooperation, the organized working for the common good, is the goal we aim at in this newer and truer socialism. Individualism meant rivalry and jealousy, a waste of energy with its consequent detriment to science; cooperationism means a unity of plan and a definiteness of purpose with its corresponding increase in efficiency. The gain from all this to the ordinary, ungrouped member of the community is at once apparent; not only would he command the very highest skill in diagnosis and treatment, but there would be no longer any need for him to subscribe to sickness clubs and similar societies, since he would

belong to a nation which was one vast mutual benefit society. He would, like the Chinaman, pay to be kept well; but if by any mischance he did become ill, he would have, as it were, round the corner all the resources of a world-wide empire to cure him.

One must gratefully acknowledge that a Department of Health has been created in Great Britain, and that in Canada by an Act which passed the House of Commons on April 14, 1919, a similar department under a deputy minister has come into existence. Some of the duties to be undertaken by this new department are: the maintenance of a national laboratory for public health and research work; inspection and medical care of immigrants and seamen and the administration of marine hospitals; the supervision of all matters relating to the health of those employed on railways, boats, ships and all forms of transportation, as well as the health of civil servants and of all government employees.

If one sketches the organization for London and Great Britain, then it could be adopted by any other part of the Empire and modified if necessary to suit the particular local conditions. Naturally, the organization of the R. A. M. C. is the one to be followed as a general model. The headquarters staff would have to reside in London and direct the service not only in London itself but throughout the whole country. The size of London makes it unique in respect of any organization, and it has to be treated as equivalent to a whole district.

After London in order of importance would come the large provincial cities, Edinburgh, Glasgow, Birmingham, Liverpool, etc., each of which would have to be administrated by a staff for itself. In each the hospitals would be so organized as to provide for in-patients, out-patients, laboratory diagnostic work, and all the necessary technical, diagnostic and therapeutic activities. The practitioners of each city would all be organized into the resident hospital service, the out-patient service and the general city service. No one of these would be considered more honorable than any other.

Associated with the great city hospital would be a group of small towns, each with its hospital, and associated with each of these would be a group of rural or cottage hospitals.

There is no question as to the S. M. S. being a costly service. It might, however, prove in actual experience not so costly as at present on paper it seems to be. For, in the first place, in a state which adopted cooperationism the enormous expenses previously needed for the upkeep of the huge navy and the

army would be saved. In the next place, a great many institutions having private endowments from public or private charities would have their funds taken over by the state as trustee, and would therefore cost the state by so much less to administer. Thirdly, the vast sums now given by public and private charities would become part of the taxes for the public health paid by everyone towards the upkeep of the service. Fourthly, the endowments of certain old and large British hospitals and seats of learning would pass over to the custody of the state. From the patient's point of view, the service would be a glorified state insurance against illness, not, of course, as a charity or on the meagre scale of a private mutual benefit society, but on that of the greatest and most enlightened empire in history. Colonel Maurice says the funds could be raised (1) out of general taxation on the budget, (2) by rates and (3) by a special public health assessment applicable to all adults according to their means.

The benefits of a state medical service are evidently twofold; those accruing to the members of the medical profession and those to the public. In the first place, as all properly qualified medical men would become registered in the national service, the quacks and irregular practitioners would soon be exposed and got rid of. Osteopaths would become licensed masseurs and nothing else. "Homeopaths" and "faith-healers" would cease to be, because they would not possess the state license to practise.

In the next place, there would be no struggle for existence, for each man would have a salary sufficient for his needs from the outset, and the prospect of a disability or old age pension, as the case might be.

The soul-destroying competitions, rivalries and jealousies of the old régime would to a large extent disappear. There would, however, be plenty of incentives to the ambitious men to rise in the profession, there would be plenty of research to be undertaken, plenty of rough places to be made plain. No one can say that there are not plenty of incentives to rise in the state professions of the Navy, the Army or the Law; and it need not be any the less so in the State Medical Service.

The advantages to those in need of treatment, are, in the stock phrase, "too numerous to mention." The public health would be preserved as never before; treatment would be prompt and of the very highest quality. Specialists of all sorts would be easily accessible, and all manner of special treatments readily available. There would, on the one hand, be no possibility of overlapping, nor, on the other, could there be whole

districts of many parts of the empire without a medical man, as at present.

In Colonel Maurice's scheme the salaries to officers in the service run from £300 a year ($1,500) to £5,000 ($25.000). Colonel Maurice says that under a state medical service the medical man would be relieved of the expenses of traveling, of instruments, consulting rooms, drugs and dressings. For the highest administrative ranks, he says "the pay would be at least equal to the highest ranks of the civil service." We may take it for certain that the scheme will be a complete failure if, in respect to pay, pensions, prestige, Royal and social recognition, titles and other rewards, this service is in any way inferior to the Civil Service. It must be recognized by the state, and it will soon thereafter be recognized by the public, that it is just as honorable to save a life as it is to blow up an enemy of one's country or sentence a criminal to be hanged.

Under cooperationism the health of the commonwealth is considered a more important affair than any other aspect of the national existence. As has been mentioned, entrance into the S. M. S. would be by the regular final examinations of the state universities, it being the understood thing that every medical graduate was destined for that service. Successful candidates would be graded according to their relative standing, and to some extent allowed the choice of positions, as in the civil service. The pay of all members would not, of course, be equal. In cooperationism there are grades of service, and remunerations vary with height therein and with responsibility. Some men prefer to remain in the lower grades with few or no responsibilities; others, capable of assuming responsibilities, are allowed to do so and are rewarded accordingly. Retirement on pension at certain ages differing with the position attained in the service would, of course, be duly provided for. The medical profession is the one doing the maximum amount of work in the interests of others, and this proposed organizing of it would be the official recognition by the state that these things are so.

In conclusion, let us look at certain objections and criticisms.

As there is nothing new, so there is nothing perfect, under the sun. The following are among the objections that have been raised to the state medical service:

1. It would do away with the patient's right of choice of a physician, surgeon, obstetrician, etc. It is asked: are rich and poor, leaders in society and persons not in society at all, the unco' guid and the declassé all to be treated by the same medi-

cal man or in the same institution? I can do no better than quote Colonel Maurice's answer to this: "It has always been the case that certain surgeons, physicians and obstetricians have earned great reputations, are in great demand and are able to command large fees; and always there have been wealthy persons prepared to pay the fees such highly considered men demand for their services. Some have special faith in one, some in another; and some only ask that some one of great renown shall operate upon them or those dear to them. There is no reason why such a system should not continue with a state medical service. The state will provide efficient attention for every citizen and will appoint to each his medical attendants, and will see to it that each can get the special skill and nursing appropriate to his or her case. Every man will be safe to trust to the organized care offered him, but if he fancy some special surgeon or physician of whom he has heard, there will be no reason why he should not choose (if he cares) to pay a special rate for that man's services. A rich man, then, has appendicitis. He has at hand in his sub-district a surgeon thoroughly competent to operate on him, and he can, if he choose, take a special ward in his district hospital for the rental charged for it, or he can, if he be frugal-minded, use the free wards and go in and be operated on by the surgeon free of all operation fee. But he has heard that some man has a specially great reputation or is fashionable because he has operated on royalty, or he fancies him for some reason or no reason. There is nothing to prevent his demanding the services of that surgeon and paying his fee. The fee will vary with the man just as it does now, twenty-five guineas, fifty guineas, a hundred guineas or more. . . . But the surgeon is the paid servant of the state, paid out of taxation or special medical contribution; he can not, therefore, be allowed to turn aside from his state service for special cases and receive double pay. He must share his fee with the state. As it is important to stimulate men to make themselves fit for the front ranks of the skilful and to stay there, it would not be politic to take all of such special fees. The great surgeon is drawing £3,000 a year from the state. His special fee is fixed at from 100 guineas to 250 guineas. He goes to the rich man, takes 100 guineas fee and gives 50 guineas to the state. So if he does one hundred such special operations in a year, he will make £10,000 a year and more for himself and the state will get back in half fees all his pay and get work from him into the bargain. Nor can such a scheme be considered unfair to doctor or

patient. To the former, ever since he entered the service, the state has assured a competency and given education and opportunity. To the patient, the state, through its carefully trained and supervised medical service, guarantees competent medical attendance at no more cost than the common taxation necessary to secure it. If through whimsicality or for more excusable reason an individual wishes to upset the state arrangement by a special call, it is not unfair that he should pay a special rate for the privilege."

In all probability something like this would happen—the hospitals belonging to a rich and fashionable district would soon be frequented by a rich and fashionable clientele; the others by others. There would be a process of natural selection on the part of patients in respect of individual physicians, institutions, districts; and in a short time, social segregation and sedimentation would have worked out society's own salvation.

So far the objections contemplated apply less to a democratic country like Canada than to a country like England, which still possesses a landed aristocracy and where social distinctions are still numerous and fairly well defined. Naturally, we could hardly expect His Grace the Duke or His Grace the Archbishop to be treated at the same clinic as his coachman or his butler. Certain hospitals would in time become so popular with a certain section of the wealthy or exclusive set that they would virtually correspond to the expensive private hospitals of the old régime.

More real as a factor working for failure is the ingenuity of human nature to wreck the fairest scheme ever put forth by the human brain. The odious system of political patronage, whereby incompetent persons can be appointed to positions intended to be filled by experts, can blast schemes that are brightest. The state medical service by its very nature and aims ought to be the one most remote from the baneful influences to which we are now alluding. The service would be administered, not by lay figureheads, but by medical men and the experts themselves. The appointees would receive their commissions not by favor, caprice or nepotism, but by merit brought out at examination.

There is no Eden without its serpent: but if any organization of human contriving might reasonably be expected to be free from the reptilian blight of political interference and mismanagement, it surely would be that of the State Medical Service.

THE ECONOMIC IMPORTANCE OF THE SCIENTIFIC WORK OF THE GOVERNMENT. III

By Dr. EDWARD B. ROSA

CHIEF PHYSICIST, BUREAU OF STANDARDS

Metallurgy, Ceramics, Aeronautics, etc.

MANY other examples of the economic importance of scientific research and standardization could be cited, if time permitted. The metallurgical industries have been greatly developed in recent years through scientific research, and there is now greater activity than ever in this field. The metallurgical division of the Bureau of Standards works in close cooperation with the engineering societies and manufacturers, and is doing work of very great industrial importance. The manufacture of glass, porcelain, tile, and other clay products has been greatly stimulated during the war by the cooperation of scientific laboratories, and vast benefit would be derived by these industries if this cooperation could be continued and even increased. The measurement of temperatures and especially high temperatures is a problem of continually increasing importance in the industries, and many scientific investigations are continually arising in this connection. The intelligent and efficient development of aeronautics depends on the possession of full and reliable information as to the properties of materials, the accurate measurement of the performance of machines, experimental researches in mechanics and aerodynamics, and the most intelligent utilization of existing and newly developed information. Considering the amount of money that is being expended in the development of aeronautics, it would seem that a very considerable amount should go into scientific research. The measurement of color and of illumination and of the optical properties of materials and the development of optical methods and instruments form together a field of investigation of great scientific and economic value. It is impossible even to mention all the subjects of importance in this connection, but enough has been said to show how vast the field and how practical the results that are obtained whenever science is appealed to in answering the problems arising in the industries.

Research by Large Corporations

The Standard Oil Company has attained a wonderful reputation for its technical and commercial success in deriving valuable products from petroleum, a result which could never have been reached without extensive scientific research.

The General Electric Company has achieved notable success in the development of electrical instruments and machinery, electric lamps, steam turbines, the applications of electricity to ship propulsion, etc., and a very large part of this success may be credited to its scientific and development work. Its research laboratories have turned out many valuable contributions to science, in addition to the results of direct application in their business. The American Telephone and Telegraph Company, and its subsidiary, the Western Electric Company, have achieved a world-wide reputation for their development of long distance telephony, multiplex telephony and telegraphy and radio telephony, as well as for the development of many of the engineering features of telephone practise of the present day.

These and other great corporations carry on research work on a generous scale and derive great commercial advantage therefrom. But thousands of smaller companies can not do what they do. The smaller companies are, however, rendering the public a service that is very essential, and the public will serve itself by helping them to improve this service. This does not mean that they will have their burdens carried for them by the government, but rather that the government as the agent of the public should participate in research and standardization work (in cooperation with manufacturers' associations and engineering societies) in order that the public may be better served and in order that the public may judge more intelligently of the quality of the product or the service rendered. It is the open door method of doing business as opposed to the method of keeping the government and the public in partial ignorance. The burden of this work when borne by over a hundred million people is very light; the benefits far outweigh the cost. The American Telephone and Telegraph Company's research laboratories employ more research workers in their single field of investigation than the Bureau of Standards does for all its many lines of work for all the industries of the country. The results obtained justify the large expense for research in the telephone field. The splendid results obtained are not due merely to the fact that the work is well managed and is done by a great corporation; but rather to the fact that abundant resources (provided by the public) are made available and an adequate scale of salaries is paid. Government laboratories could do as well if they had an equal or nearly equal chance; but they can not work miracles.

The Economic Value of Standardization

The American Engineering Standards Committee has recently been formed to promote engineering and industrial standardization. Five engineering societies and three departments of the government were represented initially in its membership. Several additional member societies have just been added and others will be added from time to time. The Committee is already actively at work in selecting sponsor societies for standardization work and approving standards. The government is rendering a valuable service to the industries, and thus to the people, by cooperating actively in this constructive and useful work. Manufacturers have not cooperated with one another in the past in standardizing designs as much as they could have done if there had been some practicable way of cooperating. They have resented government dictation and control, but they welcome government cooperation in constructive work that benefits both them and the public. In many cases the designs and sizes of machines and materials manufactured by different concerns are different because development has been independent. In other cases it is in order to have something upon which to base a claim of superiority. In either case, too many sizes and designs and lack of interchangeability increase the cost to the manufacturer, to the distributor and to the user. Nothing promotes economy and efficiency in the use of raw materials and finished products more than intelligent standardization. It reduces the varieties and sizes of materials that must be supplied by the manufacturer, lessens the stocks that must be carried by the distributor, makes the cost of the finished product less and reduces the trouble and expense to the user in caring for and keeping in repair machinery and equipment of all kinds. The high cost of the services of the plumber have been proverbial for years. Standardization in plumbing fixtures and fittings, and interchangeability of parts could be carried further than it has been. This would greatly reduce the charges for time and material in making repairs as well as in the original installation. The enormous and confusing variety of lighting fixtures, and the bad design of many, are due to utter lack of standardization or cooperation of the manufacturers with one another. Inefficient and dangerous gas appliances have been sold to the public for years, and many are still in use. The manufacturers can not be blamed, for they can not separately engage in expensive research to arrive at correct designs. The only practicable way is for all to cooperate and for the government to take an active part, helping the manufacturers to study these problems of design and standardization intelli-

gently and thoroughly. Manufacturers are glad to cooperate in such work. Since the war particularly, the high cost of labor and material have shown the necessity for economy and increased efficiency, and manufacturers are welcoming the assistance of the government as never before.

THE DUTY AND OPPORTUNITY OF THE GOVERNMENT

Such work is constructive and wealth producing, and yields returns a hundredfold upon the investment. The benefit is almost immediate and not only are there material returns in decreased costs and improved service, but such cooperation between the government and the industries is helpful both to the government and to the industries, and raises the standards of business. It emphasizes good quality and good performance and good service, and reduces misrepresentation and exaggeration in selling. Is it not the duty of the government to cooperate more actively in this constructive way with the industries? No other agency can perform this important function. The government would do only a part of the work, but that part is of great importance. Engineering societies, manufacturers' organizations, and individual manufacturing companies will do their part, and in many cases the greater part. But if the government refuses to do its part on the ground that it would increase taxation, the public will not be satisfied with the reason given when it knows that at the present time out of $50 per capita per annum collected by the government for all purposes, *scarcely more than one cent per capita per annum is expended by the government for this important work, and five cents per year per capita would accomplish wonders.* The matter is of so fundamental importance, and promises results of so great economic and social value, that it is to be hoped that some more adequate effort along this line may be made. It seems impossible that such effort would not succeed at least in part, and even a partial success would more than repay the cost.

The English Journal previously quoted says this of the government's part in scientific research. "*The endowment of research and the financing of scientific investigation are essential in any progressive nation, and if the money is well spent no amount allocated to these branches can be too great at the present stage in our country's history.*"

In Great Britain the Engineering Standards Committee is largely financed by the government, while the Department of Scientific and Industrial Research is a government body financed entirely by the government. The American Engi-

neering Standards Committee and the National Research Council (of America) are financed entirely without government aid. This is an additional reason why government research institutions in America should be so well supported that they can do their full duty in cooperation with privately supported scientific and industrial institutions which are doing work in the interest of the public.

Government Laboratories and their Trained Personnel Available for War

The war called for scientific research in connection with the standardization and making of munitions, finding and using substitute materials, locating enemy guns by sound and flash ranging, locating submarines, building and equipping ships and submarines, building and equipping airplanes, dirigibles and balloons, and many other major subjects as well as countless minor ones. This called for well-equipped scientific laboratories and the trained personnel of research workers and assistants. The government laboratories were utilized to the limit of their capacity, and all kinds of makeshift facilities were pressed into service. If preparations had been begun several years before, it is needless to say results would have been obtained sooner and the war appreciably shortened. In view of this experience, and the probability that science and technology will be no less important in the future than in the past, the question naturally arises whether the government is making adequate preparation for scientific research as a part of its program of military preparedness? In time of war the civil branches of the government will be called upon immediately for service, and they will be able to render invaluable service if they are adequately equipped and manned. In the meantime, pending the arrival of the war, which we hope will never come, they will be able to render useful service in civil problems and so be more than self-supporting. This kind of preparation for war, which adds nothing to the military budget if the civil departments are adequately supported, should appeal to all as practicable and desirable.

Summary of the Argument

The federal government having emerged from participation in the world war, finds itself with a large debt and heavy annual charges caused by the war. These together with the current cost of the army and navy amount for the present fiscal year to 92.8 per cent of the total budget. The cost of public works and the necessary administrative cost of the

federal government amounts to 6.2 per cent of the total. There remains one per cent for a large number of governmental activities classed as research, educational and developmental. The question arises whether in the interest of economy and efficiency the one per cent. shall be decreased; or because this work is constructive and of great economic value it should be increased, possibly doubled. The arguments in favor of increasing it may be summarized as follows:

1. The government should be constructive and helpful to the people and to business wherever possible. It should develop the industries, assist in improving commercial and industrial methods, and furnish technical information to manufacturers and others, as well as develop agriculture and the public domain. By rendering such service the government tends to establish good relations with business, to elevate business methods, to increase efficiency and to educate in many ways large sections of the public. The many services thus rendered cost very little in the aggregate as compared with the total expense of the government, but they are of great practical value and are appreciated by the people. *One per cent of the total expenses of the government spent in this constructive way seems a very small proportion in view of the wide range and the economic value of such work.*

2. But a part of this one per cent is incurred in behalf of the government itself, to enable the government to purchase its supplies intelligently and to do business in a business-like way. Without this research and testing work the government would waste more in buying than it would save by eliminating the research and testing. Making purchases without full technical information is embarrassing to public officials and unsatisfactory to business; whereas by always using intelligently drawn specifications and making adequate tests, the government can save money, elevate its own service and improve business methods. Much but not enough of this kind of work is now done. It is the duty of the government to set a good example before the business world of efficient and intelligent methods and fair dealing; neither accepting goods below the specified quality nor demanding more than is specified. *The government would spend less for its purchases if it spent more in standardizing the products purchased and in testing deliveries systematically.*

3. But apart from the service the government can render its citizens, and the benefit to the state resulting from scientific, educational, and developmental work, and apart from the benefit to the government of having the results of such work in constructing buildings and other public works, and carry-

ing on its business, this kind of work develops wealth, and the increased wealth can be taxed, and hence there is a third reason for increasing such work. The war has made it necessary to raise many times the revenue formerly required, and the taxation is now an important issue. Economizing in the use of raw materials, using cheaper materials, reducing waste, developing the public domain, increasing manufacturing efficiency, reducing distribution costs, all tend to create wealth and to make it easier for the government to raise the needed revenue. Therefore, if there were no other reason, this consideration should appeal to legislators and business men alike; *namely, that research and development work by the government develop wealth, and the burden of taxation is thereby lightened.*

4. But there is another powerful economic reason for increasing the productive developmental work of the government. The rising cost of living not only leads to hardship and distress, but to industrial unrest, strikes, disorders and great economic losses to the nation. In order to check rising prices, and if possible bring down prices, it will be necessary to increase production. To do this it is necessary to reduce waste and increase efficiency. This requires greater intelligence and fuller knowledge, and calls for education, the results of scientific investigation and of intelligent and extensive industrial research. The government could not and should not do it all. But neither should it refuse to do its part, and its part often is to take the lead in a constructive and statesmanlike way. It is stupid and blind to think that because taxes are heavy we can not afford to do things intelligently. If a farmer's barn burns down, he would not sell half his supply of seed and fertilizer to buy lumber, and then plant only half a crop. He would, if necessary, borrow money to buy more seed and plant a larger crop than usual, in order to increase his income and pay for the new barn more easily. *Intelligent research by the government, in cooperation with the industries, is like seed and fertilizer to a farmer. It stimulates production and increases wealth, and pays for itself many fold. It is as productive and profitable in peace as in war.*

5. Finally, if the reasons already adduced are not sufficient, there remains the military reason. The development of our intellectual, moral and material resources is the best preparation for war. Food and manufacturing facilities, and adequate supplies of raw materials and transportation systems and scientific attainments and the equipment and trained personnel available for military research, these together with an

intelligent citizenry and a just cause are the best preparation for war. A standing army and fleets of battleships are necessary but not a sufficient preparation, even if the army is armed to the teeth and the battleships are the heaviest or the swiftest in the world. The Great War demonstrated that modern wars are not of armies but of peoples, and their resources and their intellectual and industrial resourcefulness are more important than the initial equipment of armies and fleets. Therefore, a government that pays much attention to education and research and industrial developmental work is making the best preparation for possible wars of the future. *This fortunately produces good results if war never comes. By increasing the power and prestige of the nation, such preparation tends to prevent war, and so pays for itself twice over.*

Conclusion

Probably every one will grant the principle that a government should do something to educate the people, and to develop the industries and the natural resources of the country. It is only a question of the scope and extent of such work. The government has already done much, but in comparison with the needs and the opportunity it is inadequate. Cooperation of all the people in developing themselves and improving their condition and securing protection against the selfish and unfair efforts of individuals or corporations or groups, is more necessary in the modern state than formerly. And when the state contains a hundred million people and covers a continent, effective cooperation in many cases can be attained only by government assistance and leadership. Friendly governmental cooperation and constructive assistance in the industries are more welcome than regulation and repression. We must have the latter in some cases, and that is an additional reason why we should have a generous measure of the former. How far we should go experience alone can determine. But we should have the courage to face the facts, to analyze them correctly and, both in the government and in the nation, *to do as well as we know how.* We should strive for a higher and truer efficiency, for efficiency in the government, efficiency in labor, efficiency in business; and the government should not fail to do its part, which in many cases is to take the lead. If the government will cooperate with the industries in peace as earnestly and effectively as the industries cooperated with the government in war, it would be of vast benefit to the public, which pays all the costs.

DEMOCRACY'S OPPORTUNITY[1]

By Dr. STEWART PATON

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THE present moment is an interesting as well as dramatic one in the history of civilization. The recent military victory of democracy over autocracy marks progress in formulating a reply to the question to what extent man is justified in having classed himself as homo sapiens. Is he really "the wise man"? Will it be easier under a democratic than it was under the autocratic régime to substantiate his claim to the title? Does his behavior since the war presage that reason henceforth will count for more than it ever has done in the control of human affairs? Will democracy be equal to its present opportunity of assisting in the study of man with the object of finding out how thought may be liberated from the domineering control of instinct, custom and precedent, thus replacing eventually a rudimentary rationality by fully developed reason. In view of what is going on in the world, could any more important service be rendered to a government than is expressed in the purpose of this society to study man in order to find out first, what the forces are in his personality that would both quicken the development of his reasoning power and second assist in the gradual elimination from the human race of those traits that make it easy for man to-day to wish intemperately while limiting his capacity to reason connectedly. These are matters of transcendant importance.

Since eugenics calls for the solution of problems of vital importance to the race this society can not afford to be even indirectly associated with any propaganda or uplift that is purely emotionally directed and is an indication merely of the wandering of desire. The organizers of this society very wisely emphasized the word research, and thereby disclaimed all connection with the enthusiasts who rush into the field of eugenics armed only with good intention. The campaign upon which so many important issues depend should be very carefully planned. There are, however, unusual difficulties at present in trying to effect a rational organization for any purpose. One of the first steps is to be sure we have correctly visualized our problem.

[1] Address of the President of the Eugenics Association.

An unfortunate effect of the war has been to give us a false perspective: man's actual place in nature and the importance of events in his history once again have been misjudged. We need to be continually reminded of the fact that, if the history of the earth's crust is divided into twenty-four hours, primitive man first appeared on the scene during the last quarter of an hour, while civilized man—this same man who boasts of possessing huge armies and enormous guns—has existed for about twelve seconds!

Once the perspective is corrected, there is more chance that a few of the various problems perplexing us to-day will be correctly appraised with the result that we shall take many of our conventionalized opinions less seriously and shall be in a better frame of mind to consider, with all its consequences, whether man is becoming more or less rational. Probably occasional reflection upon the real, not imaginary, place occupied by man in nature would have a salutary restraining effect upon those ardent expositors of half-baked schemes for reorganizing government or improving the race who, unable to distinguish between the products of wishful- and reality-thinking, have derived their notions as to what man's capacity and needs are from the present very limited supply of facts. Man, while taking his opinions about himself very seriously, seems to ignore almost completely his defective self knowledge and except under pressure steadily refuses to observe the precautions necessary for making reason a more potent influence in the control of behavior. In as much as we are inclined to overestimate man's capacity for rational thought, we should remember how often human affairs at present are discussed in a manner that suggests the irritability and censorious manner of a psychoneurotic personality. A peculiar emotional disposition unfavorable for the development of reason increases the difficulty in reaching a just decision in regard to all questions now before the world. For this reason eugenics has a larger task than that comprised merely in the acquisition of facts. It depends for success upon the preparation the human mind has had to accept the truth whenever it is presented. As preliminary to this success, it is essential that attention should be given to the various influences now holding reason in check, and an effort should be made to remove these and leave man in a better position than he is in to-day to decide great issues intelligently. This will be a difficult task requiring both patience and intelligence.

The great question we are facing in the world is not the adjustment of boundaries, nor the settlement of European

affairs on a peaceful basis, but the real issue is whether man is capable of reacting favorably to the appeal of reason. Historians say we are passing through a crisis in western civilization, statesmen declare the principles of liberty and justice are jeopardized and that the tragedy predicted by the prophets of the eighteenth century has been enacted with an indefinite prolongation of the tragic epilogue. The significance of all this trouble expressed in simplest terms, and avoiding all show of rhetoric, is that man has become unmanageable because he is not understood. In view of the present confusion of minds throughout the entire world, and the immediate dangers arising from egotism and frenzied outbursts of pride and ambition, it is obvious that any society organized as is the Eugenics Research Association for the express purpose of finding out what constitute the desirable and undesirable qualities in the human personality and to do whatever is possible to assist in cultivating the former and eliminating the latter is actually engaged in laying the only foundation upon which democracy can ever hope to build securely.

The functions collectively designated as reason represent a final stage in man's long evolutionary history. Rationality is a collective term for a group of functions only recently acquired. Of course, it is obvious to any intelligent person that we can not understand either the nature of these functions or the conditions favorable to their development without a definite and exact knowledge of man.

Autocracy failed largely because it did not possess this information and asked to have the world made safe for a system arbitrarily selected for controlling human behavior. Germany's effort to control the affairs of the world failed because little attention had been paid to the study of man as he is.

The success of democracy depends on the cultivation of quite a different mental attitude towards the great human problem. We can not afford to imitate the blustering boastful methods of autocracy, nor to ask to have the world made safe for any particular system of organized control, until we know what the forces are that determine mental attitudes, extend the sphere of reason, and what methods may be used to minimize or eliminate the influences that distort the mind and give rise to a series of irrationally constituted opinions and a mental vision blurred by seeing the world through false refracting media.

The degree of intelligent interest and amount of support given to any well-organized movement to encourage the study of man as he is are indications of whether democracy is prepar-

ing to make good use of its present unique opportunity of placing reason in control in the direction of human affairs.

Democracy can not endure unless it succeeds in making man "the true study of man." In order to attain ultimate success there must be a clear appreciation of the nature of the methods to be applied in securing the desired information, and these methods will now be briefly described. Two distinct lines of attack are open to us in seeking for information relating to the laws governing human behavior. In the first place, there is the analytical method, also described as the elementary point-of-view, characterized by careful painstaking study of the different organs and structures composing the body. In marked contrast to this method of procedure there is the synthetic method, the study of the machine as a whole, which unfortunately has not been generally recognized by scientists as being of equal importance to the former procedure. There can not be too much analytical research, but, as George Sarton has reminded us, this must always be balanced by a corresponding amount of coordinating work. The detailed information supplied in regard to the parts and different mechanisms of the human machine must be correlated with what we know about its behavior as a living organism, adjusting to meet the demands made in the particular environment in which the individual lives. The failure to appreciate the value of the information derived from the study of human beings considered as living, functioning, biologic organisms has had not only unfortunate, but often tragic results. This oversight has resulted in the attention of physicians and psychologists being devoted almost exclusively to the use of analytical methods and has given little opportunity to demonstrate what results can be accomplished in explaining the phenomenon of behavior by the combined use of the two methods. At present, the methods used in training physicians suggests the mental attitude of those who work only in repair shops in which the human machine is taken apart and the different organs examined, but where little provision exists for following the machine on the road, observing its behavior and taking note of the immediate effect of the strain and stress of living as expressed in the complex functions of the human personality. The disadvantages of placing too much faith in the efficacy of analytical methods are easily recognized by those who take an intelligent practical interest in the subject of eugenics. Every investigator in this field should be familiar in a general way with the technic of examining analytically the different organs as practised by

expert clinicians, but in addition there should also be plenty of opportunity for becoming acquainted with the difficult art of studying the synthesis expressed in the personality.

Not only is it necessary that the investigator in eugenics should have some practical experience in the difficult technic of examining human beings, but it is equally important that he approach the problem from a broad biological point of view. He has to consider in the first place the machinery which is the product of evolution and then equally important is the observation of variations in behavior as the environment changes. We are altogether too much inclined when discussing the possibility of the inheritance of definite functions and traits to treat these as if they were specific and sharply defined qualities; and this is not the case: Another mistake often made is the tendency to regard the transmission of traits of temperament and character as the result of the functional activity only of the brain and nervous system. These so-called psychological phenomena should be discussed as biological reactions of the entire organism. In other words, we should never forget that the functions of the brain and nervous system are being continually modified by the action of other organs. When once we grasp the full significance of this principle we shall be less inclined to stress the importance of intelligence tests, or in any way to convey the impression that the consideration of the functions of any one organ, or groups of organs, may be correctly gauged without taking into account the modification produced in these reactions by a great many different factors that are too frequently overlooked or ignored.

Many of the difficulties that man has been obliged to overcome before discovering a successful method for analyzing his personality are of his own making. Progress in this direction has been unnecessarily slow on account of his tendency to create artificial distinctions in studying physical and mental processes. We should plainly recognize the fact that the investigator who approaches the study of man from the specialist's standpoint without being thoroughly drilled, not only in general biological but also in clinical principles, so that he recognizes the integrity and unity of living organisms, is bound to make serious mistakes in interpreting the phenomena of behavior.

Man's intellectual conceits and personal vanity have also told heavily against him in the efforts to know himself. He still discusses his higher intellectual functions as if these had little connection with the lower forms of adjustment, represented by adaptations at the physical level or by reactions of

lower animals. Even if this belief is seldom expressed, the mental attitude persists that is responsible for the assumption that persons who have not had practice in the clinic in the study of the functions of different organs are, without further preparation, equal to the task of analyzing the subjective phenomena represented in the personality. On the other hand, the assumption is also equally erroneous that investigators trained solely in the study of the bodily functions are equipped to undertake the analysis of the mental reactions.

The science of eugenics, as we all know, is still in its infancy, and its development should be directed along rational lines. A false step, the result of an enthusiasm often born of the best intentions, but not held strictly in check by reason, may have unfortunate results and give some justification to the reproach that this movement having as its object the improvement of racial prospects is a fad. The possible good that may eventually be accomplished by the selective breeding of human beings is a subject making such a striking appeal to the active imagination that the preliminary preparation necessary for the patient search for the essential facts may be forgotten or completely ignored.

A moment's reflection should be sufficient to convince any one of us that we can not go very far in the study of eugenics without the assistance of a body of investigators specially trained in the difficult act of studying the personality. The data supplied in personality records should be as severely criticized as are the histories of dogs or horses used for breeding purposes. Our common-sense tells us that the best judge of the good and bad qualities of these animals is the person who has had practical experience in studying canine or equine behavior coupled with some knowledge of the general anatomy and physiology of *these animals.* Exactly the same principle should be applied to the study of man. We must know something about human anatomy, physiology and psychology, and this information must be corrected and supplemented by deductions based upon the observation of the daily life of these beings. There are very few investigators trained in the art of observing human behavior. A good many people, speaking in relative terms, understand parts of the machinery and judge its performance from the angle of the physiologist or that of the psychologist interested in some particular aspect of adjustment, but there are relatively very few possessing this information who are able to tell us much about the reactions of the machine as a whole to the conditions actually met with in life. A

personality can not be judged correctly from the standpoint of either physiologist or psychologist. The specialist's approach to the problem should be broadened out so as to include the information relating to the daily life of an individual, giving some indication of how obstacles are met, overcome, or avoided.

Eugenics is confronted by the same difficulty in securing thoroughly trained observers that has been such a serious obstacle in the path of modern psychiatry. Relatively little interest is taken in the medical schools in disorders of behavior, and practically little attention is paid to training students in the complicated art of analyzing character. This indifference of the general as well as medical public to the need of making adequate provision for investigating the disorders of conduct usually described as nervous and mental diseases has had most disastrous consequences.

The high rate of incidence of specific nervous and mental disorders as well as the increasing symptoms of nervousness has become a menace to our civilization. The point to which we wish to direct attention especially at present is that the indifference of the medical profession, as well as of the public, to the study of human behavior has not only been largely responsible for the increase in these diseases, but it has created a serious difficulty in developing the science of eugenics. The fact that we know so very little about the laws governing human behavior and the organization of the personality has led, on the one side, to conditions peculiarly favorable for the increase of nervous and mental maladjustments and, on the other hand, has deprived us of the knowledge necessary for carrying on an effective campaign to eliminate the unfit and to conserve the qualities essential for human progress.

The following summary of the replies to the questionaire sent by Mr. H. H. Laughlin to the deans of medical schools in the country will give some indication of the little attention paid to the study of eugenics.

I.	No special course given and no interest exhibited in replying to questionnaire	14
II.	No special course, but subject treated in work of various departments	11
III.	No special institution, but hope to organize courses when means are available	1
IV.	No courses, but suggestions welcomed	8
V.	Same as II, but expresses marked interest	5
VI.	Same as II, but also is taught in connection with sociology	2
VII.	No special courses given. Eugenics referred to in connection with one of following subjects—surgery, pathology, embryology, anatomy, zoology	12

VIII.	Express regret that no instruction is given	1
IX.	Referred for information to other members of the faculty, from whom no answer was received	3
X.	School discontinued—Total	53

The work of gathering together a body of well-trained investigators would be aided materially by establishing scholarships in our medical schools for those intending to pursue the study of eugenics. For some time we should not attempt to do more than to carry on a campaign with the object of eliminating the unfit. In order to determine what the undesirable qualities are, it is necessary that those conducting the examinations should be capable of determining to what extent the environment has become a potent factor in changing the personality. In order to do this an examiner should be thoroughly conversant with methods used by the modern psychiatrist in the examination of patients. It is very often the case that undesirable qualities supposed to be transmitted directly by inheritance prove upon examination to be merely the results of repressions in members of a family who have tried to adjust themselves to an environment unsuited to their biological requirements. A change in the surroundings may lead to astonishing results and the supposedly inherited biological tendencies are quickly replaced by more successful forms of adjustment. We do not refer, of course, to the cases of mental defects due to organic causes and which are evidently a direct product of inheritance. We should not make the mistake, however, of entrusting the diagnosis of mental defectiveness to those whose limit of experience in the examination of human beings makes it necessary for them to draw sharp artificial lines of distinction between physical and mental reactions.

A great deal of work is yet to be accomplished in laying the foundations of the science of eugenics before positive direct recommendations for improving the racial prospects are made to the public; except urging the use of selective methods in breeding to eliminate the unfit. Careful consideration should be given to the problem of training investigators in the very difficult part of studying the personality. The analysis of temperament and character can not be undertaken successfully by amateurs. Something could be done to improve the methods used in the study of personalities in relation to the problem of eugenics by establishing fellowships in the medical schools for investigators intending to enter this special field of research. A good deal may also be accomplished in this same direction by improving the facilities for making personality studies that are

present in the psychiatric clinics. The assistants who are to direct the work of analyzing human predispositions and the special traits of character and intelligence will be drawn chiefly from those having had experience in the work of these clinics. While we are discussing the foundations upon which the science of eugenics should be established, we should not omit a reference to the scant provision now made for the study of the brain and nervous system. We are accustomed to refer to normal and abnormal conditions in the structure and functions of these organs as if exact standards of comparison had already been established; and this is not the case. Practically little is known about the great mechanism of adjustment, and it is astounding how indifferent man seems to be in regard to his most recently acquired and valued possession, his new brain. Adequate provision should be made for studying the nervous system as this field of investigation has important connection with the science of eugenics.

The crisis confronting us to-day is a real one, and many people are gradually becoming conscious of the significance of the problem upon which current events are forcing a decision. Behind discussion about social readjustments, rearrangement of international boundaries, and a League of Nations, all of which are practically minor issues, stands the open question whether man is entitled to be designated as "homo sapiens." Do the events through which we are passing mark the beginning or end of the period of rational thought in the evolution of man. Is the triumph of democracy the beginning of a decline to the dead level of mediocrity? We have accustomed ourselves to rely upon wishful-thinking for answer to these questions. Probably if we decide to make the effort, an intelligent reply can be formulated. If democracy assists in making man the true study of man, the chances are that intelligence will become a much more dominant factor in the control of human behavior while mankind will be in a better position both to judge what the racial prospects are and to accept and apply the teachings of eugenics.

THE METHOD OF PROCEDURE IN THE ANALYSIS OF HEREDITY

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WHATEVER the conception we may have of the essential nature of the activities of living things, it must be agreed that as time goes on more and more of them can be pictured in terms of demonstrable mechanical models. I shall leave to others the questions: Why does the biologist get any satisfaction out of such constructions and why does he not rather busy himself with the determination of absolute values?

The first step toward a satisfactory basis for the understanding of the nature of the transmission of hereditary qualities was the proof that organisms as we know them are never derived from non-living things. They are always separated parts of a parental organism something like themselves. This simple proposition was not demonstrated until the last century. From the earliest times it was commonly believed that certain animals at least can be generated from non-living material by the action of external agents. If such a generation is possible it seriously affects our notions regarding the transmission of hereditary qualities. As far as we now know every organism starts as part of a preexisting organism. Our question then is the manner in which this part of the parental body carries the qualities of the future adult individual.

That the qualities of the separated part or germ cell are really of great importance in the development of the new individual, as compared with environmental forces, may be readily demonstrated by placing a fish egg and a frog's egg side by side in a dish of water. The surroundings are the same for both and yet one develops into a fish and the other into a frog. No environmental differences can produce effects at all comparable with these. The relation of these biological facts to certain sociological theories is obvious. The primary differences between human beings as between other organisms are due to hereditary factors and not to environmental factors.

Some have claimed that one egg develops into a fish because it has a non-material force or entelechy which wants it to develop into a fish while the other egg has an entelechy which wants to it develop into a frog. If it were impossible to

make out any units of a lower order than the eggs, if they were the ultimate particles with no visible differences between them, in despair of any other explanation one might postulate that differences in their activities are due to such non-material forces. This is no more than the physicist does with his ultimate particles, though he does not often admit it. On the other hand, more physicists than biologists are anxious to prove that the smallest known particles of organisms have souls.

However, since the egg is not an ultimate particle and it is possible to make out something of the structure and activities of its various parts, the biologist tries to picture to himself the way in which these parts are related to the adult characteristics. He tries to determine how they would act if they were large enough to be handled.

PREFORMATION AND EPIGENESIS

From the time of the earliest philosophers some have denied the problem of individual development by claiming that the egg contains the parts of the adult in miniature and that development is merely an enlargement of these parts. On the other hand, some have denied the presence of structure within the egg and have claimed that development starts with no structure and gradually works toward the complexity of the adult. It will not be worth while to follow here the early history of this controversy between the preformationists or evolutionists, as they were called, and the opposing school of the epigeneticists. It may suffice to say that opinion alternated from one extreme to the other. In the seventeenth century, when the first compound microscopes were used to examine eggs and spermatozoa, the observers were so convinced that the human body was present in miniature that they promptly found it there and published their findings in elaborate drawings of the little mannikin with its limbs nicely folded up like the petals in a flower bud. Those of us who have had to do with students in biological laboratories recognize that people have not changed in this regard during the centuries. It is still very easy to see what you are looking for and still very hard to see things that do not fit into your preconceived notion.

With the construction of better microscopes it was soon made evident that the little mannikins do not exist and there was an early swing of opinion to the opposite extreme. Practically all biologists became epigeneticists, claiming that the egg

is a homogeneous protoplasm in which the adult structures are gradually developed.

Since the middle of the last century, however, there has been a gradual return from this extreme position. Improvement in microscope lenses has made possible a rapid advance in the knowledge of the structure of organisms. It has been shown that organisms are made up of smaller units, the cells, that the ovum and spermatozoon are such units and that all the numerous cells of the adult body are derived from the subdivision of a single cell, the fertilized ovum. Furthermore, it was shown that there is a complicated but very definite mechanism within all cells. Experimental work has demonstrated a specific relation between this mechanism within the egg and the adult structure. The general trend, therefore, is toward a modified preformation. The parts of the adult are not entirely unrepresented in the egg, as in the view of the extreme epigeneticists, nor are they represented by exact miniatures, as in the view of the extreme preformationists or evolutionists. Instead there is a recognition of a definite, specific relation between certain structures and activities in the egg and certain other structures and activities in the adult.

Nucleus and Cytoplasm

The first step in the analysis is the recognition of the difference in function between the cytoplasm and the nucleus of the egg. Within the egg as in every cell two portions can be recognized, a central body called the nucleus surrounded by the remaining substance called the cytoplasm. During the last fifty years a large amount of evidence has been collected which proves that the nucleus and cytoplasm have different functions not only in the ordinary life of the cell, but also in their relations to the transmission of hereditary qualities.

Histological studies have shown that the visible differences in the different tissues of an organism are almost wholly if not wholly in their cytoplasms. The essential differences that we make out between the different cells of the body have to do with cytoplasmic structures. Thus the muscle fibrils, the nerve fibers, the pigment granules and similar modifications in the tissues are all cytoplasmic. There is reason to believe, however, that the nucleus has some causal connection with their appearance.

It has been demonstrated that while both nucleus and cytoplasm must be present in order that development may

occur, they are by no means of equal value in the process. In certain eggs if the nucleus is left undisturbed the greater part of the cytoplasm may be removed without affecting the development of a complete normal individual, and it does not matter what part is so removed. Thus while the nucleus alone can not develop, a small amount of cytoplasm from any location is sufficient to cause it to do so. On the other hand, when the cytoplasm remains intact not only the removal of a part of the nucleus, but even a disarrangement of its materials is sufficient to prevent the development of a normal individual.

Another point in the evidence is the fact that, while on the whole the female and male parents contribute equally toward the qualities of the child, the cytoplasmic contribution of the spermatozoon is negligible in amount. On the other hand, the amount of nuclear material furnished by egg and spermatozoon is essentially equal in amount and, as we shall see, this similarity applies to the details of nuclear structure. Furthermore, the nucleus and not the cytoplasm contains a mechanism in agreement with the facts of experimental breeding.

THE CHROMOSOMES

It is in the nucleus then that we are bound to seek this further mechanism of heredity. Our evidence for such a conclusion has been accumulating very rapidly during recent years, and it is not possible to do more than give some of the striking points.

A detailed microscopical study has shown that there is within the nucleus a material, called chromatin because of its affinity for certain dyes, which behaves in a remarkable manner during each cell division. This material is present in the period between cell divisions in the form of granules. Preceding a cell division, these granules arrange themselves in a row or rows, producing a thread or threads of granules which soon break up into definite segments or chromosomes. These chromosomes are perfectly definite bodies, always the same in number in any species of animal, always breaking up into their constituent granules between cell divisions and always being built up again at every cell division from the egg to the adult. A beautiful structure somewhat resembling the diagrams of a magnetic field is then developed, with two poles, the centrosomes, and with radiations extending in all directions from them. The rays passing from one pole to the other constitute what is known as the spindle. The chromosomes

arrange themselves in a transverse plane at the center of this spindle, each one splits longitudinally, and the two halves travel to opposite poles. The cell then constricts at its equator and two daughter cells are produced each containing a longitudinal half of each of the chromosomes. The whole elaborate mechanism has this one important function of bringing about the exact distribution of chromatin material, so that each daughter cell gets not only the same total amount as the other, but also exactly the same amount of each part of each chromosome. By the repetition of this process every cell in the adult body finally has exactly the same chromosomal complement as every other cell.

It follows from this fact that, on the chromosomal hypothesis, every cell contains a complete set of developmental determiners. Then, why do some cells form muscles, others nerves, still others connective tissue and so on? Weismann's theory involved the assumption that the cell divisions were actually qualitative and that the different cells of the body obtain different complements of chromatin. As stated there is no observational basis for such a conclusion. We are therefore forced to the hypothesis that each cell has all of the materials and the question of why it uses some and not others remains to be solved by other means. The discussion of this problem, however, can not be undertaken here.

There is an interesting modification of this process of equal distribution of chromosomes, during the last two divisions of the germ-cells, those immediately preceding the time when they are ready for fertilization. During the early divisions of the germ cells there is no essential difference between them and other cells, but at one of the last two divisions instead of the ordinary procedure of a longitudinal splitting of each of the chromosomes which would insure the original number in each of the daughter cells, there is no splitting at all. Two whole chromosomes come to lie side by side in the equator of the spindle and each of the daughter or mature germ cells gets a half of the total number. There is thus a reduction to one half of the original number of chromosomes. This takes place in both the male and the female germ cells. For a reason to be mentioned presently, it is customary to speak of this reduced number as n and of the number in the division of ordinary cells as $2n$. It is obvious since spermatozoon and mature ovum each contain n chromosomes that when they unite in fertilization the $2n$ number is restored.

There are a number of other interesting points in connection with this reduction in the number of chromosomes. It

has been shown that a mature unfertilized egg may be caused to start development in other ways than by union with a spermatozoon. The method is not important, since the same result may be brought about by a great many different kinds of agents, as chemical change in the medium, osmotic change, rapid change in temperature, pricking with a needle or even by shaking. The cells of individuals developed in this way have only the *n* set of chromosomes from the ovum, yet they produce complete individuals. Likewise, a small piece of the cytoplasm of the egg without any nucleus may be entered by a spermatozoon, and the nucleus of the resulting fusion contains only the *n* chromosomes of the male. Yet a whole individual results again. It is clear, therefore, that if the chromosomes contain the essential factors in the development of the characters of the individual, the egg contains a complete set of such factors and the spermatozoon contains another complete set. The fertilized egg and all of the cells of the body derived from it must therefore contain a double set.

This is in agreement with the facts obtained by experimental breeding as first made out by Mendel in 1866. Since its rediscovery in 1900 the principle involved in the so-called Mendelian inheritance has been shown to be a general one. A great many hundreds of characters in both animals and plants have been shown to follow it.

The essential point in these phenomena, as pointed out by Mendel before there was any knowledge of a chromosomal mechanism, is that the body of an organism contains a double set of factors, one or more pairs for each of its characters. Any character then is dependent upon the presence of at least two factors, one derived from the male and the other from the female, and these two factors must separate again when the sex cells are produced. Each sex cell then can have only one member of the original pair. Of course, this fact can only be demonstrated when the factor coming from the male is different from that coming from the female, as in hybridization. If in such a case we call the factor coming from one parent *A* and that from the other parent *a*, then the resulting individual will have the constitution *Aa*. When it produces sex cells half of them must carry *A* alone and the other half *a* alone in order to get the proportions obtained in experimental breeding which are one fourth with *AA*, one half with *Aa* and one fourth with *aa*. As Mendel observed, the *A* and the *a* show no contamination as a result of their intimate association within the same body. They are as pure as they were in the original parents.

Mendel showed further that in case there is present in the

same mating another pair of characters due to another pair of factors as *B* and *b*, their distribution is independent of the distribution of *A* and *a*. In the second hybrid generation there is thus a combination of characters which is the one to be expected on the view of independent assortment of the two pairs of factors.

It happens that the behavior of the chromosomes is such as to furnish an ideal mechanism for this distribution of factors. If we place the hypothetical factors for the Mendelian characters in the chromosomes of our model they are distributed in exactly the proper way to give rise to the numerical proportions of Mendel's law.

Differences in the factors contained do not, however, as a rule cause visible differences in the chromosomes which carry them. There is only a single demonstrated case of such a difference and that is in the inheritance of sex. This case is therefore of the greatest interest. In order to make the explanation as simple as possible, I shall take only one of the kinds of differences that have been made out. In a great many animals there is an exception to the rule that $2n$ chromosomes are present in the cells of the body. Instead there are $2n-1$ chromosomes in the cells of the males, while the females have the ordinary number $2n$. When mature eggs are being produced there is the ordinary reduction in the number of chromosomes to one half and all obtain n chromosomes. In the spermatozoa there can not be such an equality because $2n-1$ is an odd number. Accordingly, when the chromosomes pair off in preparation for the maturation divisions, one is left without a mate. One of the daughter cells obtains n chromosomes and the other only $n-1$. Accordingly, half of the spermatozoa are of one kind and half of the other. It follows that since all eggs are alike in having n chromosomes the result of random or non-selective mating gives half of the individuals with $2n$ chromosomes, or the number in the female body cells, and half with $2n-1$ the number in the male body cells.

Another result follows from this consideration. If the factors for other characters than sex are located in these chromosomes they should be distributed according to a scheme differing from that of other characters. This follows from the fact that in the case of such characters half of the spermatozoa should lack entirely any factor for them. Numerous such sex-linked characters are known.

If the chromosomal hypothesis is correct, it follows further that the number of independently heritable characters as far as random distribution is concerned should be limited to the

number of pairs of chromosomes in the species in question. If the factors for two characters are located in the same chromosome they should go together or be linked according to the technical expression. Such linkage has been demonstrated frequently. Furthermore, there is no known case in which there are more independent groups of linked characters than there are pairs of chromosomes. The form in which the heredity of the greatest number of characters has been worked out is the fruit fly *Drosophila* with over 200 to its credit. There are only four pairs of chromosomes and correspondingly the characters are linked in inheritance in four groups. Furthermore, one of the four pairs of chromosomes is very small and correspondingly one of the linked groups of characters is much smaller than the others.

This striking mass of evidence from normal inheritance is confirmed by the experiments with abnormal distribution of chromosomes. The two cases I shall choose in illustration approach the problem from opposite sides.

Boveri produced an abnormal distribution of the chromosomes during the first cleavage of the egg by inducing two spermatozoa to enter the egg at once. He then separated the daughter cells. This was in the sea-urchin egg, a form in which under normal conditions separated cells produce complete individuals. Only a certain percentage of these daughter cells had full sets of chromosomes. The same percentage developed into complete individuals.

Bridges attacked the problem from the other side. In some of his fruit-fly material the inheritance of the characters did not follow the ordinary Mendelian formula. He figured out the kind of chromosomal abnormality that would yield such a result. He decided that the breeding data would follow if, in the maturation of the egg cell, the members of the pair of chromosomes involved did not separate as in normal reduction, but went to the same pole, leaving one of the daughter cells with both members of the pair and the other without any. An examination of these cells made after the formulation of this explanation showed that such an abnormal separation had actually occurred.

These experiments with irregular distribution clinch the argument that the chromosomes are the bearers of factors having to do with the appearance of characters.

THE CHROMOMERES

Within the last few years an extension of our knowledge has shown that the chromosomes can not be considered as the

elementary units in the transmission of hereditary qualities. An analysis of the differences in value between different parts of individual chromosomes is therefore being made.

The possibility of such an analysis was already indicated by the microscopical observations previously mentioned, which showed that the chromosomes are themselves made up of rows of granules. These individual granules are known as chromomeres. It will be recalled that when the chromosomes are formed during cell division each one is made up by the coming together of the granules present in the resting stage of the cell. A large number of cytological observations have made it seem probable that when a chromosome breaks up into its constituent granules or chromomeres at the end of a cell division, these granules do not mix up with others in the nucleus, but occupy a definite region in it. This is made out especially well in certain lobed nuclei in which the separate regions belonging to the individual chromosomes can be definitely mapped out. It is probable therefore that the same granules form homologous chromosomes in succeeding cell generations.

It follows also from the nature of the division of a chromosome that when it splits longitudinally into two equal parts, each granule or chromomere is also split into two equal parts and, therefore, each daughter cell obtains not only a half of each of the chromosomes, but also a half of each of the constituent granules. Each cell of the completed body, therefore, has its equal share of each of the minute chromatin granules present in the egg.

Supposing each granule or chromomere to represent a different kind of material, each cell of the organism has a complete set of materials. All the cells are then qualitatively alike in this respect. The quantitative relations are restored between succeeding cell divisions by growth, as each chromomere is able to build up new material like itself.

It is probable that here in the chromomeres are elements in the mechanism of heredity of a lower order than the chromosomes. If the chromomeres of a chromosome always stick together or if the linkage of characters within a group is never broken there is no way of testing such a hypothesis. Fortunately we have evidence from both sides of such a breaking of linkage.

From the side of experimental breeding, evidence has accumulated that while, according to the hypothesis that the chromosomes are indivisible units, linked characters should stick together, they do not always do so. This breaking of the linkage was subjected to careful study, particularly in the

fruit fly, *Drosophila,* and it was shown that the breaking never takes place in the formation of the spermatozoa but only in the formation of the eggs. Furthermore, taking a linked group such as that which is found in the same chromosome as the sex-determining factor, the percentage of breaking of the linkage between any two factors is fairly constant. If the percentages between characters *a* and *b* and between *b* and *c* are known, that between *a* and *c* is either the sum or the difference of the others. The fifty or so characters in this linked group all fit into this linear arrangement. A line with the factors located upon it can be drawn, in which the distance between any two points, representing the location of factors, corresponds to the percentage of breaking of linkage between those two points. Such diagrams have been carefully constructed. For instance, the percentage of separation of the characters yellow body and white eye is 1.2, of white eye and bifid wing 3.5, and of yellow body and bifid wing 4.7, or the sum of the other two.

As stated, this linear arrangement, in which the distance between any two factors is proportional to the percentage of separation of the characters, is fairly consistent but not wholly so. There is a tendency for the high values calculated from the sums of two components to be somewhat higher than the actual ones. The suggested explanations will be given later.

It is perfectly natural to suppose that this linear arrangement on the basis of percentage of separation of the factors in breeding may represent an actual linear arrangement within the chromosomes. This necessitates the postulate that the chromatin granules as they pass from the resting stage preceding a cell division always arrange themselves in the same definite, fixed order when they form a chromosome. It is only recently that there has been any cytological evidence bearing on this point.

Assuming that the granules actually do lie in a fixed order, to explain the facts of the breaking of linkage it is necessary to discover a mechanism by which the granules of one chromosome may be exchanged for those of its mate as the two lie side by side at the beginning of the maturation divisions of the egg.

It will be remembered that the two chromosomes which lie side by side in this manner come from separate parents. It was supposed that they always separate as units, but it has been known for some years that they frequently twist around each other, and may indeed seem to fuse at the point where one

crosses the other. It was supposed until recently that when the members of the pair separate to travel toward opposite poles they have undergone no exchange of material. If, however, there is a real union at the nodes it is perfectly probable that parts of the two may be interchanged. For instance, if we take the case of a single twist, one end of chromosome *A* may be united with the other end of chromosome *B*, on the one side of the figure, with the reverse relation, on the other side. A factor located near one end of a chromosome is thus separated from one located near the other end. It is obvious that the nearer together two factors are within a chromosome the less chance there is that the crossing over of a twist will come between them. The percentage of such separation of characters in experimental breeding may then be taken as a measure of the distance apart of the factors in the chromosome assuming that the "twistability" of the chromosome is the same at all points. It is further natural to assume that the chromomeres are the seats of these separate factors.

It has already been mentioned that the percentage of separation between *a* and *c* tends to be somewhat less than the sum of the percentages between *a* and *b* and between *b* and *c*. This may be explained on the supposition that two twists sometimes take place between the more widely separated points and the result of two twists is the same as that of no twist as far as the factors in question are concerned. The percentage is therefore decreased for the greater distances. That such double crossing over occurs has been proved in other ways.

The fact of twisting of chromosomes has actually been observed in a number of cases, but the behavior of the chromomeres is hard to make out with any degree of certainty because they are near the limit of visibility even under the highest powers of the microscope. It is impossible, therefore, at present, to confirm by actual observation of the hereditary substance the hypothesis of exchange of material between the chromosomes in the manner just described. On the whole, the general evidence is favorable to the view, but there are still a number of difficulties. One of these has to do with the fact that crossing over takes place only in the female.

As far as the sex linked characters are concerned there is no difficulty, because in the male the sex chromosome either has no mate or has one with which no crossing over can occur. It is only in the female that crossing over is possible and the cytological evidence, therefore, is in agreement with the data of experimental breeding. With regard to the characters that

are not sex linked, there is, however, no satisfactory cytological explanation of the difference between male and female. A careful study is now being made by several workers particularly of the more difficult female material, and it is to be hoped that some definite conclusion may be reached on this important point.

Castle has recently attempted to show that a closer approximation to the data of percentage relations may be obtained by supposing that the factors do not have a strict linear arrangement. The hypothesis has also to meet difficulties due to the fact that the percentage of crossing over may be changed in various ways, though none of these changes affects the linear arrangement.

On the whole, the chromomere hypothesis still lacks some important elements before it can compare with the chromosome hypothesis in degree of demonstration. It has, however, already led to a number of very important discoveries regarding the method of inheritance and can therefore be said to have justified itself.

CONCLUSION

By correlating the data from experimental breeding with those from the microscopical examination of the germ cells, the biologist has been able to demonstrate the existence of a mechanism which explains many things about the manner in which characters are transmitted from generation to generation. To a large extent, the model is based upon the action of parts actually visible and clear to all observers. As the limit of visibility under the highest powers of the microscope is approached, as in the case of the chromomeres, there is however, a difference of opinion as to the facts. The imagination then comes into play and it may be that some of the structures figured are purely creatures of the imagination, just as the mannikins of the seventeenth-century observers were. This probability, however, does not invalidate the clearly demonstrated features of the model.

Having this model in mind, the biologist can plan manipulations similar to those which he would practise upon a machine large enough for the parts to be handled directly. A very great many discoveries of importance in the field of heredity have been the results of such imaginary manipulations.

But the biologist is not content to stop with the visible elements of his model. The cell, the nucleus and cytoplasm, the chromosomes and perhaps the chromomeres, are definite parts of a mechanical model that works in practise. But why do the

chromomeres act as they do? Why is one different in its action from others? The biologist now becomes a philosopher. He tries to picture to himself further extensions of the model he has built so far, on the basis of demonstrable data. On the basis of past achievement he is inclined to believe that the chromomeres differ in their action because they differ in structure and related function. Therefore they are not the ultimate units of the structure. It is natural for him to try to connect them with the units of the physicist and chemist, the so-called chemical elements and the electrons. But the gap between his model and that of the physicist is still too great to enable him to make any considerable use of the latter. The method of procedure in the two cases is much the same, but perhaps the construction of the physicist is the more speculative one.

As I have said, when the biologist comes to the last demonstrable elements of his model he is inclined to suppose that in the future it may be indefinitely extended by the same method of procedure which he has previously pursued and that it may at some time be linked up with the units of the physicists. Curiously enough, several eminent physicists have strongly contested such a possibility. They seem much more inclined than are the biologists to put a limit upon such an extension and to assume the existence of non-material factors. Perhaps they do not realize what the biologist knows all too well, namely, the hopeless sterility in the past of all such ideas of non-material factors. The devising of non-material factors is an interesting mental exercise. Men have been busy with it from the earliest times. But there is no indication that any considerable advance in our knowledge of organisms has been obtained in that way. Of course this does not prove that the truth may not lie in that direction. Since the great majority of people find satisfaction in postulating such non-material forces in explanation of observed activities, it is perhaps well that the small minority who find some satisfaction in constructing their incomplete mechanical models will never be able to make their models complete. For no matter how far such models are extended they will always finally end up in units, which will furnish opportunity for the ever-ready remark, "Aha! there you have something which your model does not explain. Must you not assume a non-material factor to explain *its* action?" The only answer that can be given is the one already stated—that as time goes on more and more of the activities of living things can be pictured in terms of demonstrable mechanical models.

A SIMPLIFIED MUSICAL NOTATION

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With an Introduction

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INTRODUCTION

The complications of musical notation have been for generations the despair of students, teachers, theorists, and executants. Difficulties attendant on reading music in various keys and clefs, in correctly performing elaborate groups of chromatic notes, and in selecting, for composition, one enharmonic use as being more suitable than another—these, with other difficulties, have not only retarded the progress of musical education, but have actually prevented multitudes from coming into direct association with music. It is indeed paradoxical that music, which, of all the arts, makes the most instant appeal, should have so hedged itself about with complicated and confusing symbols. By a process simple, logical, and musically sound, Professor Huntington has destroyed the terrors of chromatic notation.

Many persons reading the title of this article and observing the author to be by profession a mathematician will say, "This is probably some scientific speculation. There is no chance that our notation will be changed, so why read all this?" But open-minded and intellectually honest musicians will read these paragraphs, and will ask themselves a very different sort of question.

A. T. DAVISON

A SIMPLIFIED MUSICAL NOTATION

THE purpose of this paper is to present a new musical notation which, while retaining all the excellent features of the present notation, would, it is believed, greatly simplify the processes of reading, studying and composing musical scores.

The plan is not one of the artificial mnemonic devices of which the literature is full,[1] but is based directly on the fundamental principle of modern music, namely, the equi-tempered

[1] For a critical account, see C. F. Abdy Williams, "The Story of Notation," Scribners, 1903.

scale. This scale, introduced by J. S. Bach about two centuries ago, and now dominating all musical composition, makes use of *only twelve notes in each octave,* these twelve notes dividing the octave into twelve mathematically equal intervals, called semitones. Now, if we draw an ordinary five-line staff with one ledger line, we see that exactly twelve notes can be accommodated on the lines and spaces of such a staff. *What is then more natural than to assign one place on the staff to each of the twelve notes of the scale, thus doing away with all "sharps" and "flats," and representing every musical interval correctly to the eye as well as to the ear?* This, in brief, is precisely the plan here proposed.

The details are easily completed. We assign the notes commonly known as C, C♯ or D♭, D, etc., to the places indicated in Fig. 1.

Fig. 1.

In speaking of the note "C♯ or D♭" in conversation, either name may be used indifferently, since the two names (in the modern temperament) are simply synonyms for the same note. But in reading or writing a score, on the proposed plan, this single note is represented by a single degree of the staff, unmodified by any sharps or flats. In other words, every note used in modern music has one and only one place on the staff, and every degree of the staff represents one and only one note.

Moreover, the proposed representation of every octave is simply a repetition of every other octave, so that no "clefs" (treble, 𝄞; base, 𝄢; tenor, 𝄡; etc.) are required. The successive octaves from low bass to high treble may conveniently be numbered consecutively from 1 to 8, "middle C" falling between the fourth and fifth octaves, as shown in Fig. 2.

This Fig. 2 illustrates how clearly the range of pitch of any musical instrument can be exhibited in the new notation. The striking contrast between the old method and the new in this respect is shown in Fig. 3, the data for which are taken from Cecil Forsyth's "Orchestration" (Macmillan, 1914).

The chief merit of the new plan is that *every musical interval, and hence the structure of every musical chord, is repre-*

sented correctly to the eye by the relative distances between the notes on the staff.

For example, the intervals in Fig. 4*a* and Fig. 4*b*, which look so different in the old notation, are really equal intervals, represented in the new notation as in Fig. 4*c*.

This direct correspondence between the ear-interval and the

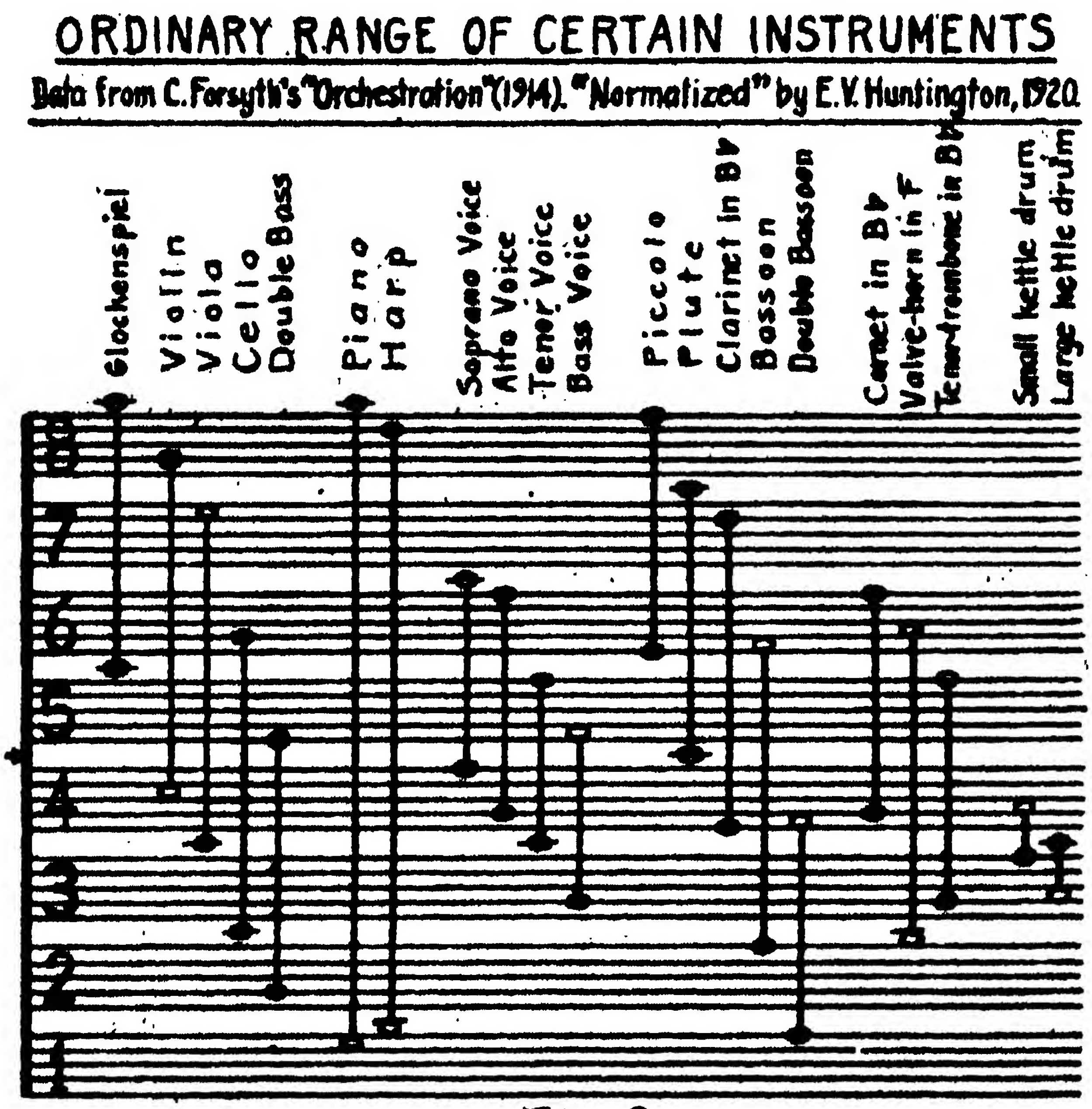

Fig. 2.

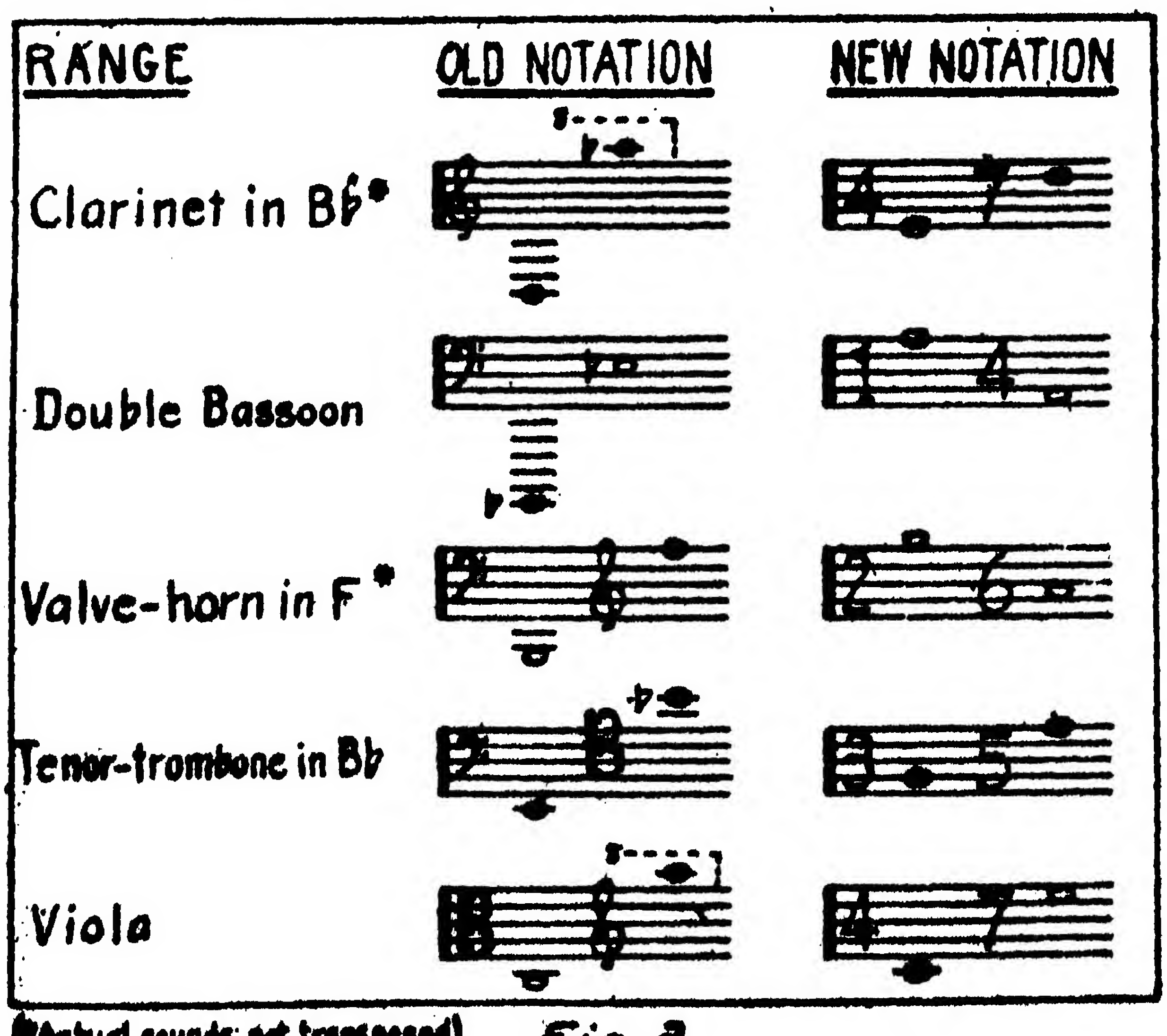

Fig. 3.

eye-interval would seem to be a great advantage in sight-reading, both for singers and for players. In particular, the labor of *transposition from one key to another* is greatly simplified in the new plan; for, since the relative position of the notes is unchanged, the process of transposition may be regarded as

(a) (b) (c)

Fig. 4

merely a shifting of the background of lines and spaces, with no thought of key-signatures, accidentals, etc., that are now so troublesome. A similar remark applies to the transposed scales which are often used in writing for special instruments, to facilitate fingering.

These are all the points that need be mentioned in order to make the scheme of the new or "normalized" notation clear. No change is made in the present mode of indicating the duration of a note (quarters, ♩; eighths, ♪; etc.) or the time (3/4 time, 4/4 time, etc.) or in the present symbols indicating expression (f, pp., pedal, etc.). The important change is the abolition of the "sharps" and "flats" which have been the trial and perplexity of pupils for so many generations. These sharps and flats, whether occurring as accidentals, or in the key-signature, may now be recognized as merely the result of an attempt, historically explicable, but necessarily unsuccessful, to crowd twelve notes into seven degrees of the staff, instead of providing each note with its own place.

In order to show the great simplification that the new notation would bring with it, a few bars from a complicated modern score[3] are here given in both the old and the new notations (Fig. 5). A further illustration is given in Figure 7.

It will be observed that much vertical space required in the old notation to allow for ledger lines between the bass and treble staves is saved in the new notation; also, some lateral space required for accidentals may be saved, without danger of crowding the notes. Hence, in spite of what one might expect when eight degrees of staff are expanded into twelve, the total space required on the page is only slightly increased by the new plan—certainly not more than twenty per cent. This slight objection would appear to be much more than offset by the advantages secured.

Moreover, in the case of band music, where condensation is

[3] Maurice Ravel, "Valses nobles et sentimentales," I, page 3; A. Durand & Fils, Editeurs, 1911.

Fig. 5.

especially desirable, the score for each instrument can, by simple devices, be compressed into a single staff.

What has been said so far has had reference to the reading of a musical score by the performer.

It remains to point out the effect of the new plan on the problems of teaching and analysis.

For purposes of elementary teaching there would seem to be great advantages in the principle of "one sound, one symbol." To avoid rhythmic complications in scale singing, however, the names of the notes should be monosyllabic. It may be desirable, therefore, to call the twelve notes of the scale by the last twelve letters of the alphabet, pronounced as follows:

O	P	Q,	R	S	T;	U	V	W,	X	Y	Z
Oh	Pee	Que,	Are	Ess	Tee;	You	Vee	Dub,	Ek	Eye	Zee.

The scale of C major would then be sung as

O — Q — S T — V — X — Z O

or, if preferred, the "do, re, mi" syllables could be used with fixed pitch, as in the present French schools:

do — re — mi fa — so — la — ti do

The details of such matters must of course be left to the teachers.

For purpose of analysis, the present names, "C," "C # or D ♭," "D," etc., may of course be retained if preferred.

It is on the side of analysis that the only serious theoretical objections to the new plan are likely to be raised.

For one thing, the guidance to key-changes which accidentals in the present scores now provide would be lacking in the new plan; again, the fine distinctions known as enharmonic changes would cease to have any significance.

In reply to these objections, it may be said that whatever is actually present in the music as heard by the ear is faithfully reproduced in the new notation as seen by the eye. Hence it follows that the new notation omits nothing which is really essential for the analysis of the music as sound. *All that it discourages is an analysis of the symbolism of an obsolete notation.*[3] As Grove's Dictionary states, all our present rules for notation are based on the old Mean-tone temperament which made a real distinction between C# and D♭. They do not apply to the modern equal temperament in which these two symbols represent exactly the same sound. Now what the new notation does is to register accurately the sounds which are actually heard to-day. Any desired analysis of the relations between

[3] As a matter of fact there are no "rules" for chromatic notation. Even as early as Beethoven one finds the chromatic scale variously notated in the same composition. The question of the employment of C# or D♭ is usually a matter left to the whim of the composer.

those sounds can therefore be carried on entirely adequately in the new notation.

Moreover, the analysis of the relations between the actual sounds would be really easier in the new notation than in the old. For, in the new notation, on account of the direct correspondence between the ear-interval and the eye-interval, the structure of the chords that are being analyzed may be immediately recognized by their geometric "shape." In fact, a beginner might have bits of celluloid or tracing paper, marked with certain standard configurations, to use as a sort of touchstone to apply to any chord he might wish to examine.

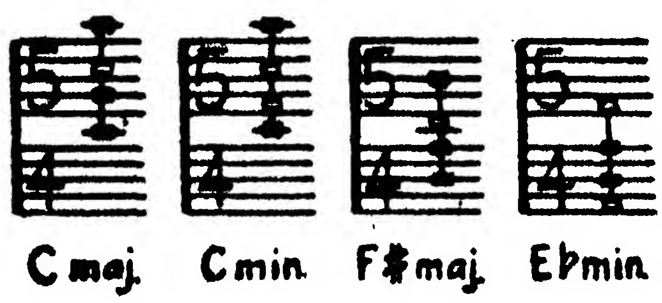

Fig. 6.

Finally, it should be noted that any composer who desires to record the key of any composition can do so more readily in the new notation than in the old. Thus, a "key-signature," though not at all necessary, may be indicated, at any point, by simply noting the fundamental chord of the key, as in Fig. 6.[4]

The supposed objections are thus seen to be more apparent than real. In fact, the new notation might well lead to a new point of view in analysis, a point of view in which all questions of mere "spelling" would be relegated to the background, the entire attention being directed to the study of the actual sounds.

It is not the writer's purpose to discuss at this time the practical difficulties in the way of getting the proposed plan adopted. One need have no illusions as to the seriousness of these difficulties. The first essential would be, of course, to secure the publication of a great collection of standard and school music in the new notation. If this could be done on a large scale, many teachers and pupils would doubtless be glad to avail themselves of the "normalized" scores, the use of which might easily save a large part of the time and expense now required for an elementary musical training. New editions of standard works are constantly being published; it is not impossible that a decisive number of these new issues might

[4] By the addition of an occasional single letter (Ellis's "duodenal"), the new notation can even be made to indicate the notes required for "just intonation" with complete accuracy. A discussion of this phase of the subject is reserved for another occasion.

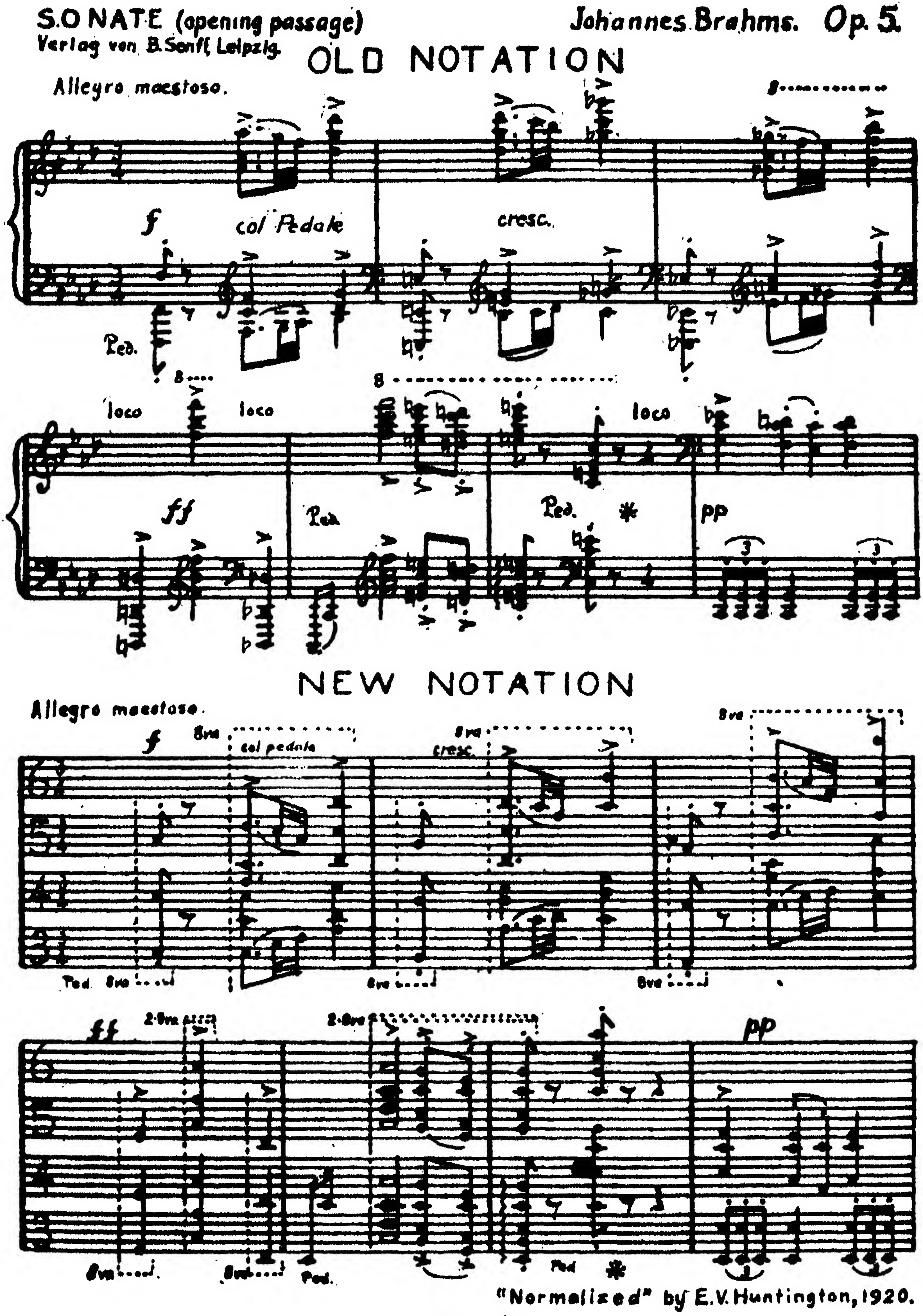

Fig. 7.

be published in the "normalized" notation. Few steps would do more, in the long run, to encourage the practise, by the people at large, of the art of musical expression.

THE PROGRESS OF SCIENCE

THE FOREIGN BORN AND NEGRO POPULATION OF THE UNITED STATES

THE Bureau of the Census is making public the population of the states and of cities according to the enumeration of the fourteenth census taken in April last. In view of the disturbances due to the war, the detailed study of the composition and distribution of the population will be of special interest, and

THE TOTAL POPULATION AND ITS ELEMENTS AT EACH CENSUS: 1850-1910

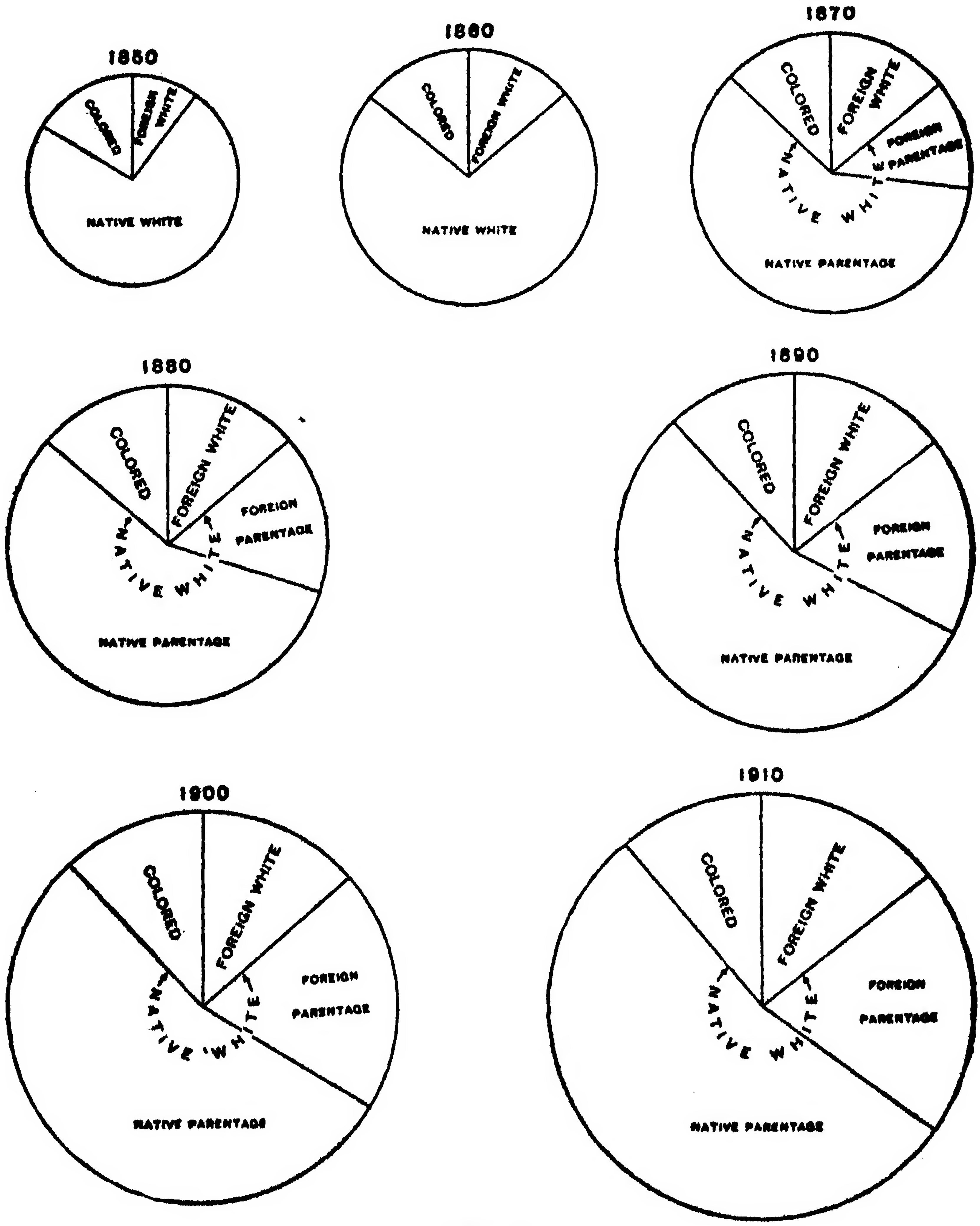

FIG. 1.

PER CENT OF FOREIGN-BORN WHITES AND NATIVE WHITES OF FOREIGN OR MIXED PARENTAGE COMBINED IN THE TOTAL POPULATION, BY STATES: 1910

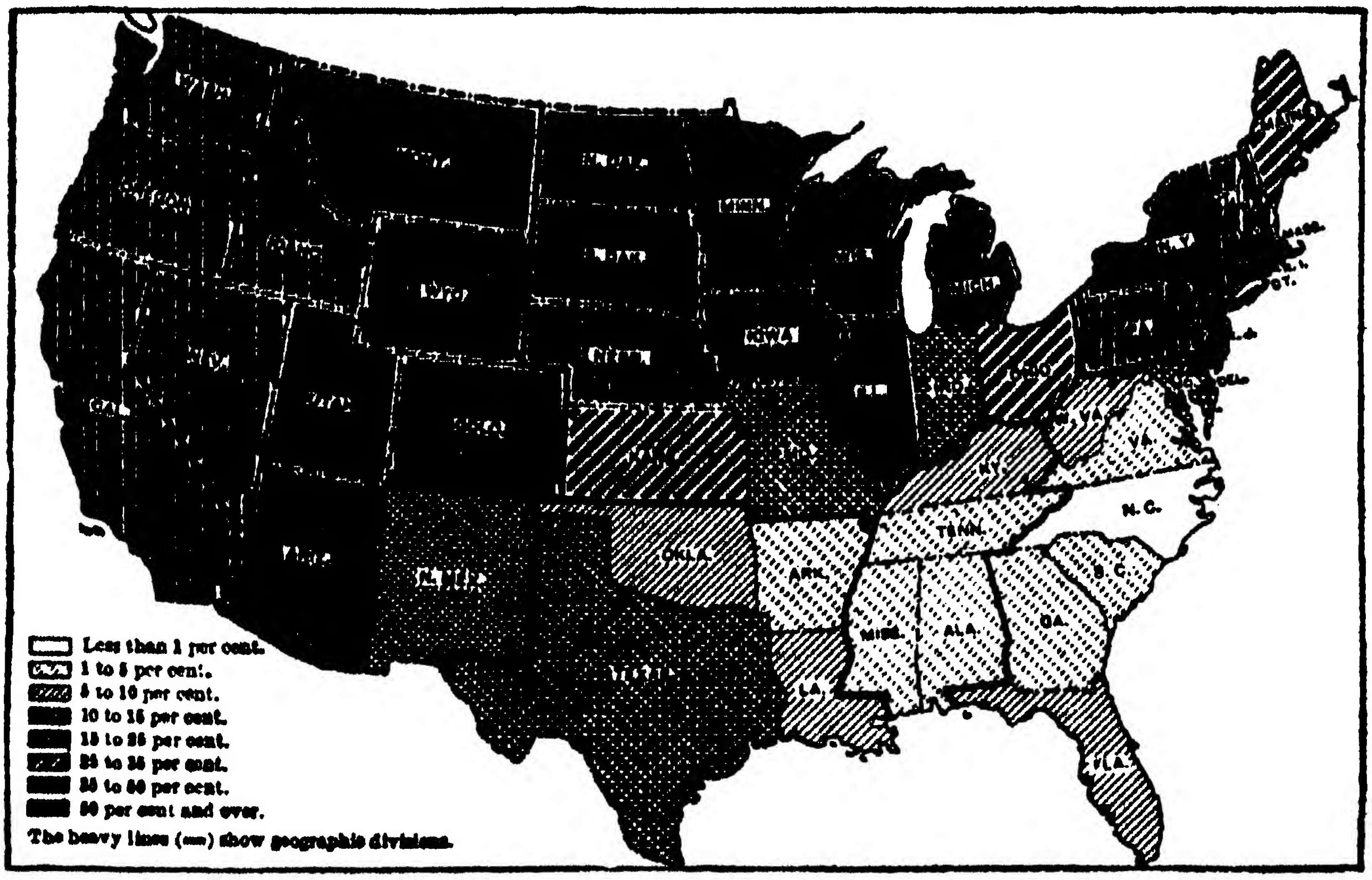

FIG. 2.

it is to be hoped that the compilation and publication of the results will be completed without delay. In the meanwhile it may be worth while to give some figures for the census of 1910, taken from the Statistical Atlas published by the Bureau of the Census in 1914.

In Fig. 1 the population of the United States is represented by circles, proportionate to the number returned at each census, from 1850 to 1910, the divisions of the circle indicating the proportion of the population in each of the principal classes. The great increase in the foreign element, including both foreign born and the native of foreign parentage, is brought out very clearly. The proportion of colored population is practically the same at each enumeration, but the proportion of native white of native parentage has steadily decreased.

Fig. 2 indicates, in eight groups, by the character of the shading, the percentage of foreign-born whites and native whites of foreign or mixed parentage combined in the total population in 1910. The solid black, indicating 50 per cent. or more, covers 13 states, while the next groups, 35 to 50 per cent., also covers 13 states, and indicates that for 26 states 35 per cent. or more of the population is of foreign birth or parentage. These 26 states have 53.3 per cent. of the total population of the United States. The state with the lowest percentage is North Carolina, which has less than 1 per cent. All the states of the South Atlantic and East South Central divisions, except Delaware, Maryland, West Virginia, Florida, and Kentucky, also the District of Columbia, have less than 5 per cent. of the foreign-born element in their population.

Fig. 3 presents, by states, the per cent. distribution of the negroes in 1910, in seven groups, shaded as indicated in the legend. Mississippi and South Carolina have the highest per cent. of negroes and are the

PER CENT OF NEGROES IN TOTAL POPULATION, BY STATES: 1910

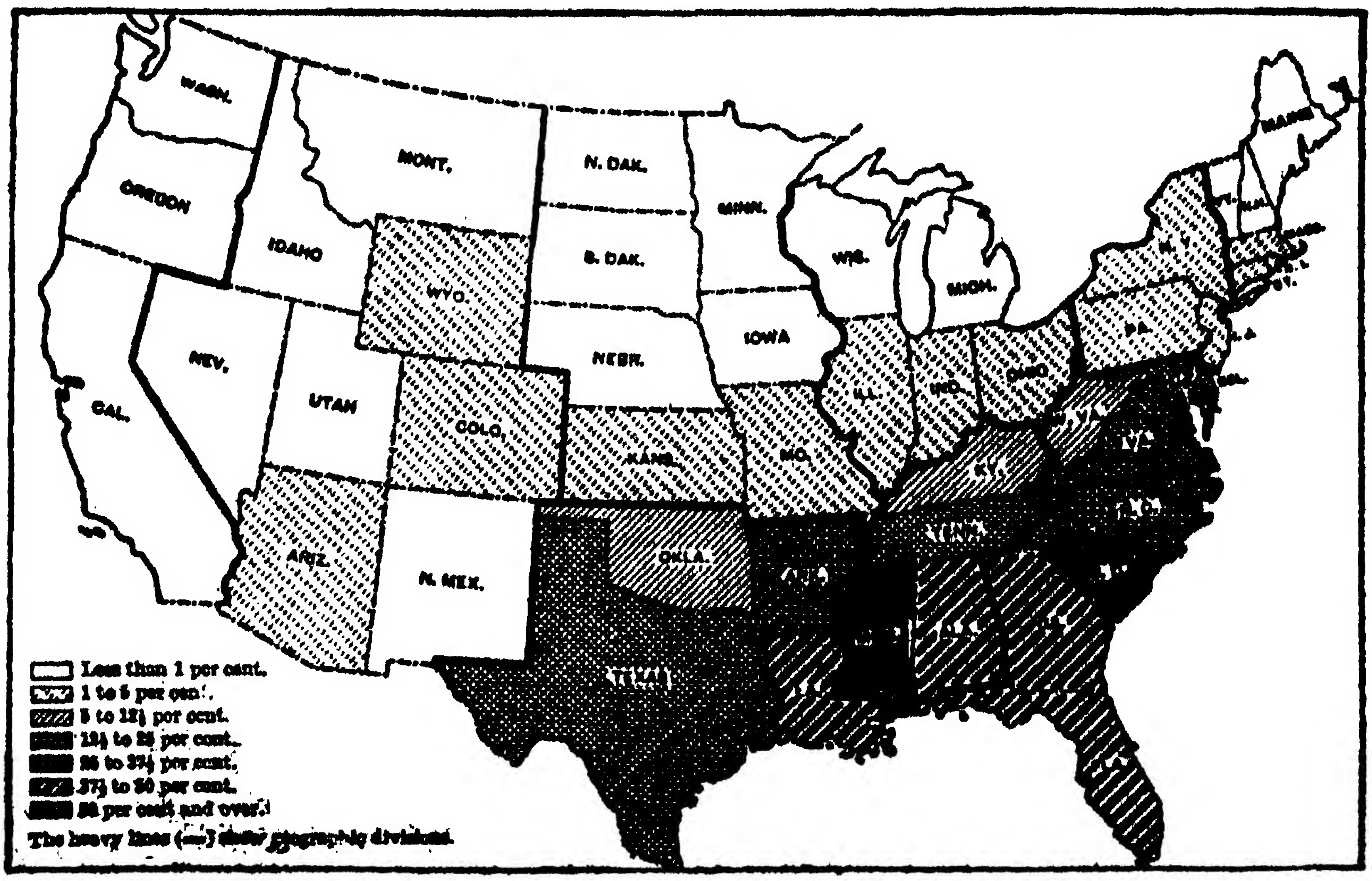

FIG. 3.

only states with more than 50 per cent. of their population negroes. South Carolina had a larger proportion of negro population than any other state at each census from 1790 to 1890, but in 1900 the number of negroes in Mississippi had increased to 58.5 per cent., while in South Carolina the per cent. had fallen to 58.4. In 1910 Mississippi had the highest percentage, 56.2, and South Carolina was second, with 55.2.

PROPORTION OF MALES TO FEMALES IN THE TOTAL POPULATION, BY STATES: 1910

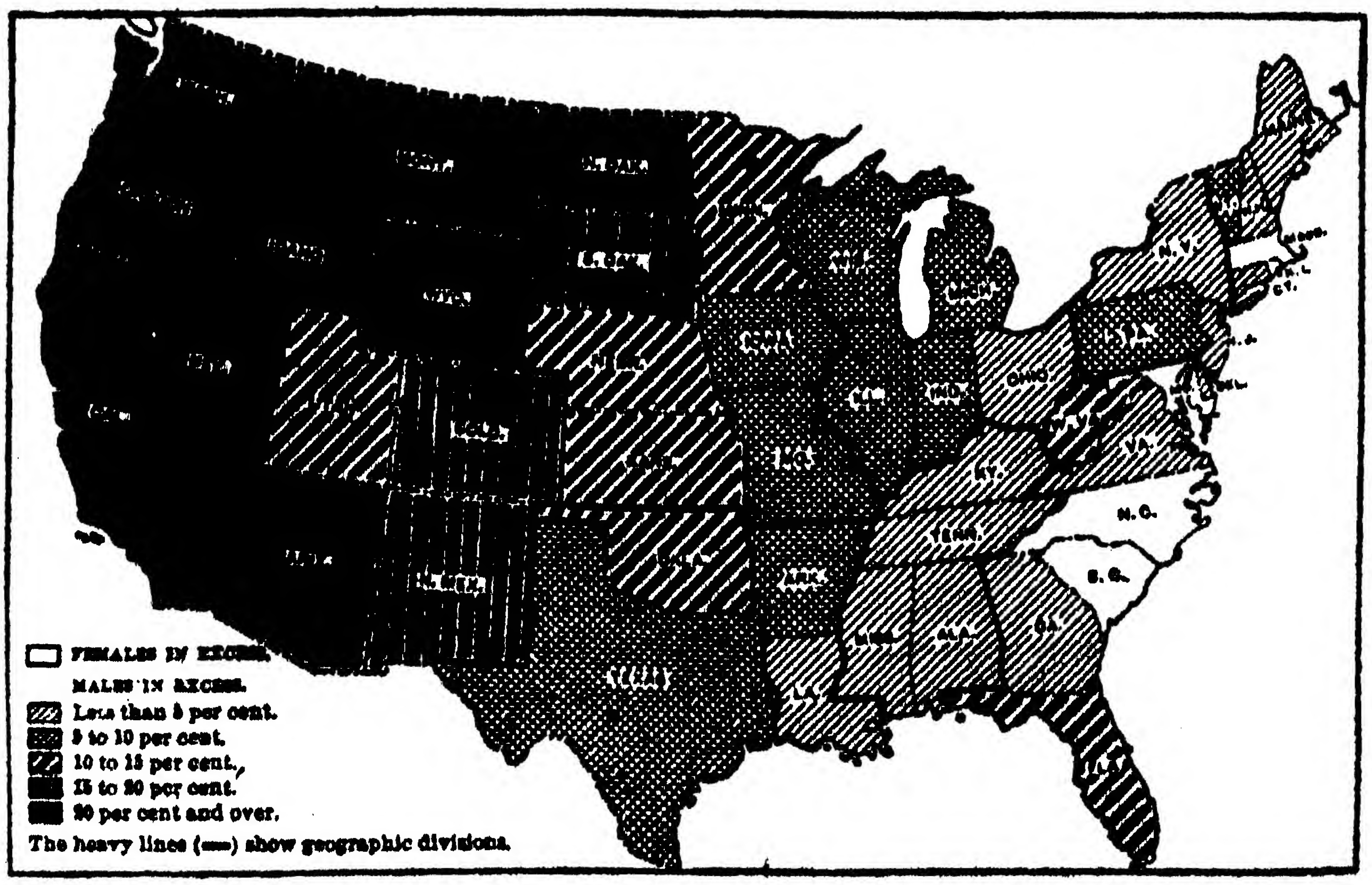

FIG. 4.

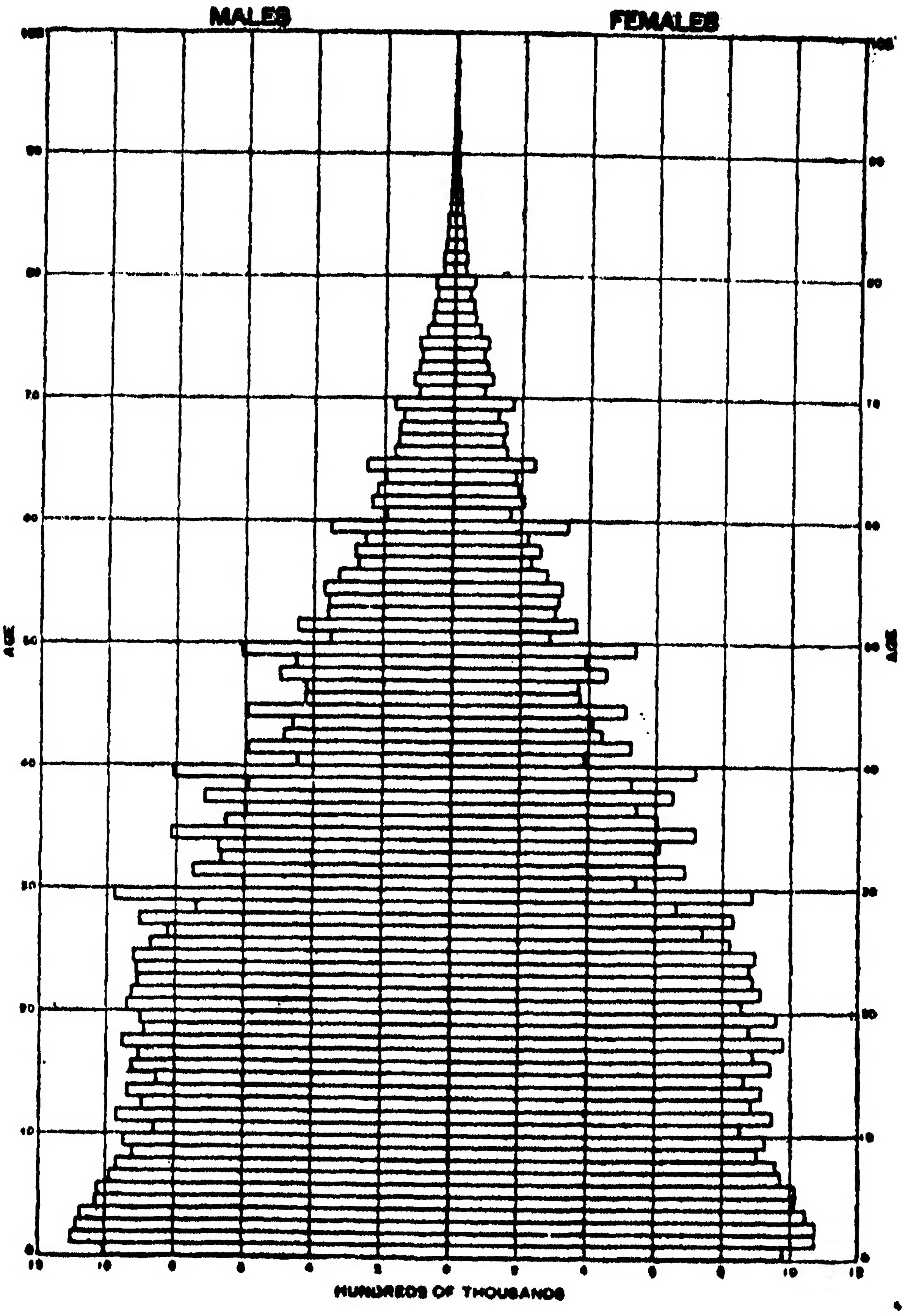

FIG. 5.

DISTRIBUTION OF THE POPULATION BY SEX AND AGE

Fig. 4 indicates the proportion of males to females in the total population at the thirteenth census, by states. The females are in excess in Massachusetts, Rhode Island, Maryland, District of Columbia, North Carolina, and South Carolina. In 1910 the states having the greatest proportion of males to females were Nevada, with 179.2, Wyoming with 168.8, and Montana with 152.1 males to each 100 females. The proportion for the United States is 106 males to each 100 females. The excess of males is due principally to the large foreign immigration, in which the males largely outnumber the females. The map brings out the fact that no geographic division east of the Mississippi River had, in 1910, more than 106 males to 100 females, the United States average, but in all of the western divisions the proportion is much higher, the Pacific division reaching a total of 129 males to 100 females. This is due to the migration of the native male population from the eastern states to California, Oregon, and Washington. The sections which have been recently settled in that part of the country give more opportunity for the labor of men than of women.

Distribution by age and sex of the total population by single years of

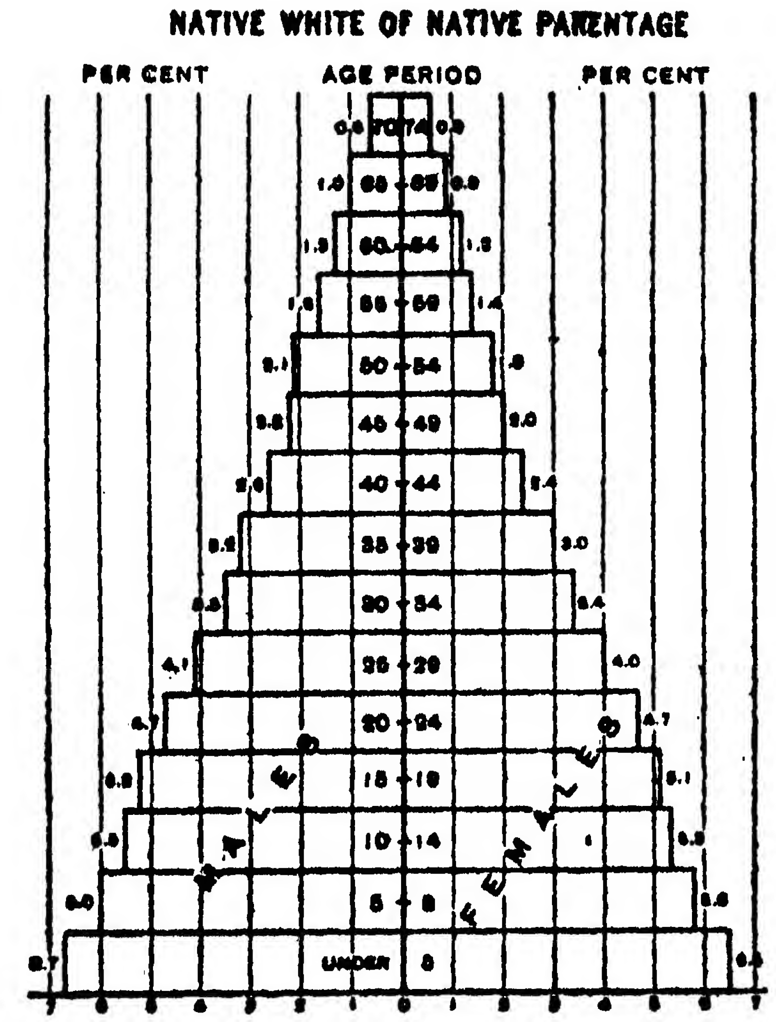

FIG. 6.

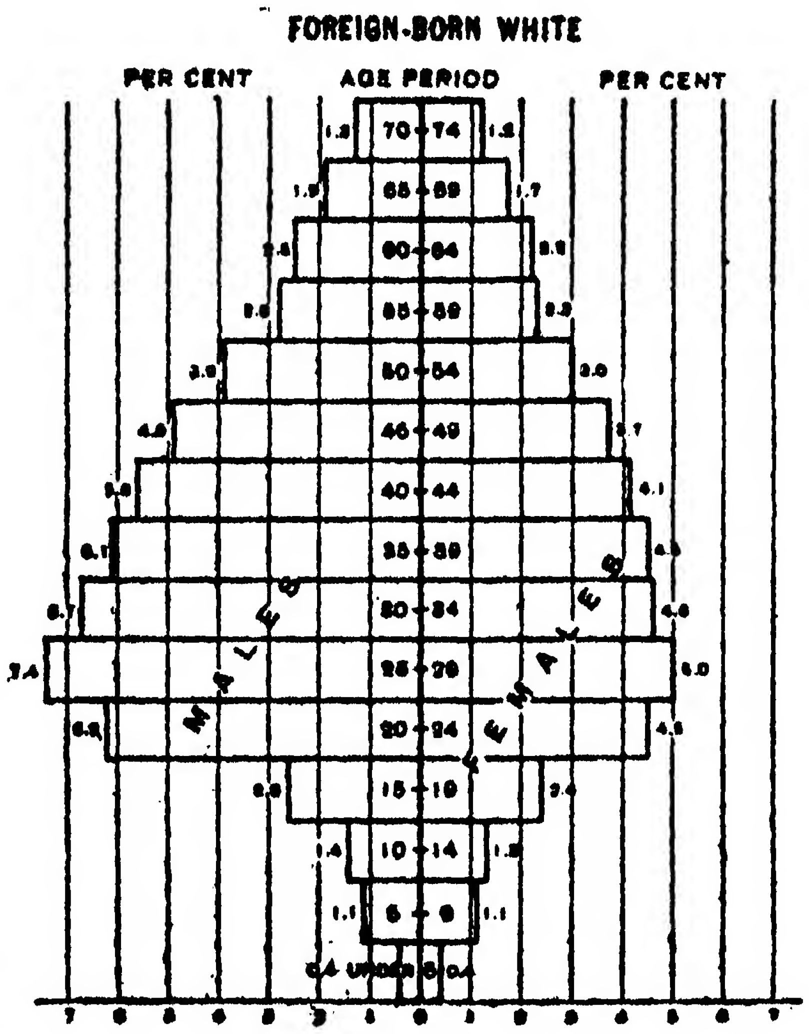

FIG. 7.

age, as shown in Fig. 5, presents very strikingly the irregularity in the proportion of the ages of the population as returned in 1910. A normal diagram should form a pyramid, each bar representing an age period being smaller than the one below it. The sexes are nearly equally divided, but the abnormal length of the bars, especially for the periods ending in zero or in 5, stand out in the diagram. Many more individuals say they are thirty years old than twenty-nine or thirty-one. The fact that fewer children are reported in the first year of life than in each of the four subsequent years indicates the defects or difficulties in the way of taking a census.

The extent to which the age and sex distribution of the population is influenced by immigration is shown in Figs. 6 and 7. Among those arriving from foreign countries the men greatly exceed the women and there are comparatively few children. Families are the most desirable class of immigrants and the laws should favor them rather than discriminate against them as is now the case.

SCIENTIFIC ITEMS

WE regret to record the death of Sir Norman Lockyer, director of the London Solar Physics Observatory and for fifty years editor of *Nature*.

CAMBRIDGE UNIVERSITY has conferred the degree of doctor of laws on Dr. John J. Abel, professor of pharmacology at the Johns Hopkins Medical School, and on Dr. Harvey Cushing, professor of surgery in Harvard University.—Dr. William W. Keen, professor emeritus of surgery at the Jefferson Medical College, president of the International Surgical Society, recently in conference at Paris, presided at the opening sessions.

THE SCIENTIFIC MONTHLY

OCTOBER, 1920

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE[1]

OCEANOGRAPHY AND THE SEA-FISHERIES

By Professor WILLIAM A. HERDMAN

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

OCEANOGRAPHY has many practical applications, chiefly, but by no means wholly, on the biological side. The great fishing industries of the world deal with living organisms, of which all the vital activities and the inter-relations with the environment are matters of scientific investigation. Aquiculture is as susceptible of scientific treatment as agriculture can be; and the fisherman, who has been in the past too much the nomad and the hunter—if not, indeed, the devastating raider—must become in the future the settled farmer of the sea if his harvest is to be less precarious. Perhaps the nearest approach to cultivation of a marine product, and of the fisherman reaping what he has actually sown, is seen in the case of the oyster and mussel industries on the west coast of France, in Holland, America, and, to a less extent, on our own coast. Much has been done by scientific men for these and other similar coastal fisheries since the days when Prof. Coste in France in 1859 introduced oysters from the Scottish oyster-beds to start the great industry at Areachon and elsewhere. Now we buy back the descendants of our own oysters from the French ostreiculturists to replenish our depleted beds.

It is no small matter to have introduced a new and important food-fish to the markets of the world. The remarkable deep-water "tile-fish," new to science and described as *Lopholatilus chamæleonticeps*, was discovered in 1879 by one of the United States fishing schooners to the south of Nantucket, near the 100-fathom line. Several thousand pounds weight were

[1] Extracts from addresses given at the Cardiff Meeting.

caught, and the matter was duly investigated by the United States Fish Commission. For a couple of years after that the fish was brought to market in quantity, and then something unusual happened at the bottom of the sea, and in 1882 millions of dead tile-fish were found floating on the surface over an area of thousands of square miles. The schooner *Navarino* sailed for two days and a night through at least 150 miles of sea, thickly covered as far as the eye could reach with dead fish, estimated at 256,000 to the square mile. The Fish Commission sent a vessel to fish systematically over the grounds known as the "Gulf Stream slope," where the tile-fish had been so abundant during the two previous years, but she did not catch a single fish, and the associated sub-tropical invertebrate fauna was also practically obliterated.

This wholesale destruction was attributed by the American oceanographers to a sudden change in the temperature of the water at the bottom, due in all probability to a withdrawal southwards of the warm Gulf Stream water and a flooding of the area by the cold Labrador current.

I am indebted to Dr. C. H. Townsend, Director of the celebrated New York Aquarium, for the latest information in regard to the reappearance in quantity of this valuable fish upon the old fishing grounds off Nantucket and Long Island, at about 100 miles from the coast to the east and southeast of New York. It is believed that the tile-fish is now abundant enough to maintain an important fishery, which will add an excellent food-fish to the markets of the United States. It is easily caught with lines at all seasons of the year, and reaches a length of over three feet and a weight of 40 to 50 pounds. During July, 1915, the product of the fishery was about two and a half million pounds weight, valued at 55,000 dollars, and in the first few months of 1917 the catch was four and a half million pounds, for which the fishermen received 247,000 dollars.

We can scarcely hope in European seas to add new food-fishes to our markets, but much may be done through the cooperation of scientific investigators of the ocean with the Administrative Departments to bring about a more rational conservation and exploitation of the national fisheries.

Earlier in this address I referred to the pioneer work of the distinguished Manx naturalist, Professor Edward Forbes. There are many of his writings and of his lectures which I have no space to refer to which have points of oceanographic interest. Take this, for example, in reference to our national sea fisheries. We find him in 1847 writing to a friend:

> On Friday night I lectured at the Royal Institution. The subject was the bearing of submarine researches and distribution matters on the fishery question. I pitched into government mismanagement pretty strong, and made a fair case of it. It seems to me that at a time when half the country is starving we are utterly neglecting or grossly mismanaging great sources of wealth and food. . . . Were I a rich man I would make the subject a hobby, for the good of the country and for the better proving that the true interests of government are those linked with and inseparable from science.

We must still cordially approve of these last words, while recognizing that our Government Department of Fisheries is now being organized on better lines, is itself carrying on scientific work of national importance, and is, I am happy to think, in complete sympathy with the work of independent scientific investigators of the sea and desirous of closer cooperation with university laboratories and biological stations.

During recent years one of the most important and most frequently discussed of applications of fisheries investigation has been the productivity of the trawling grounds, and especially those of the North Sea. It has been generally agreed that the enormous increase of fishing power during the last forty years or so has reduced the number of large plaice, so that the average size of that fish caught in our home waters has become smaller, although the total number of plaice landed had continued to increase up to the year of the outbreak of war. Since then, from 1914 to 1919, there has of necessity been what may be described as the most gigantic experiment ever seen in the closing of extensive fishing grounds. It is still too early to say with any certainty exactly what the results of that experiment have been, although some indications of an increase of the fish population in certain areas have been recorded. For example, the Danes, A. C. Johansen and Kirstine Smith, find that large plaice landed in Denmark are now more abundant, and they attribute this to a reversal of the pre-war tendency, due to less intensive fishing. But Dr. James Johnstone has pointed out that there is some evidence of a natural periodicity in abundance of such fish and that the results noticed may represent phases in a cyclic change. If the periodicity noted in Liverpool Bay[2] holds good for other grounds it will be necessary in any comparison of pre-war and post-war statistics to take this natural variation in abundance into very careful consideration.

In the application of oceanographic investigations to sea-fisheries problems, one ultimate aim, whether frankly admitted

[2] See Johnstone, *Report Lancs. Sea-Fish. Lab.* for 1917, p. 60; and Daniel, *Report* for 1919, p. 51.

or not, must be to obtain some kind of a rough approximation to a census or valuation of the sea—of the fishes that form the food of man, of the lower animals of the sea-bottom on which many of the fishes feed, and of the planktonic contents of the upper waters which form the ultimate organized food of the sea—and many attempts have been made in different ways to attain the desired end.

Our knowledge of the number of animals living in different regions of the sea is for the most part relative only. We know that one haul of the dredge is larger than another, or that one locality seems richer than another, but we have very little information as to the actual numbers of any kind of animal per square foot or per acre in the sea. Hensen, as we have seen, attempted to estimate the number of food-fishes in the North Sea from the number of their eggs caught in a comparatively small series of hauls of the tow-net, but the data were probably quite insufficient and the conclusions may be erroneous. It is an interesting speculation to which we can not attach any economic importance. Heincke says of it:

> This method appears theoretically feasible, but presents in practise so many serious difficulties that no positive results of real value have as yet been obtained.

All biologists must agree that to determine even approximately the number of individuals of any particular species living in a known area is a contribution to knowledge which may be of great economic value in the case of the edible fishes, but it may be doubted whether Hensen's methods, even with greatly increased data, will ever give us the required information. Petersen's method, of setting free marked plaice and then assuming that the proportion of these recaught is to the total number marked as the fishermen's catch in the same district is to the total population, will only hold good in circumscribed areas where there is practically no migration and where the fish are fairly evenly distributed. This method gives us what has been called "the fishing coefficient," and this has been estimated for the North Sea to have a probable value of about 0.33 for those sizes of fish which are caught by the trawl. Heincke,[8] from an actual examination of samples of the stock on the ground obtained by experimental trawling ("the catch coefficient"), supplemented by the market returns of the various countries, estimates the adult plaice at about 1,500 millions,

[8] F. Heincke, *Cons. Per. Internat. Explor. de la Mer*, "Investigations on the Plaice," Copenhagen, 1913.

of which about 500 millions are caught or destroyed by the fishermen annually.

It is difficult to imagine any further method which will enable us to estimate any such case as, say, the number of plaice in the North Sea where the individuals are so far beyond our direct observation and are liable to change their positions at any moment. But a beginning can be made on more accessible ground with more sedentary animals, and Dr. C. G. Joh. Petersen, of the Danish Biological Station, has for some years been pursuing the subject in a series of interesting reports on the "Evaluation of the Sea."[4] He uses a bottom-sampler, or grab, which can be lowered down open and then closed on the bottom so as to bring up a sample square foot or square meter (or in deep water one tenth of a square meter) of the sand or mud and its inhabitants. With this apparatus, modified in size and weight for different depths and bottoms, Peterson and his fellow-workers have made a very thorough examination of the Danish waters, and especially of the Kattegat and the Limfjord, have described a series of "animal communities" characteristic of different zones and regions of shallow water, and have arrived at certain numerical results as to the quantity of animals in the Kattegat expressed in tons—such as 5,000 tons of plaice requiring as food 50,000 tons of "useful animals" (mollusca and polychæt worms), and 25,000 tons of starfish using up 200,000 tons of useful animals which might otherwise serve as food for fishes, and the dependence of all these animals directly or indirectly upon the great Beds of Zostera, which make up 24,000,000 tons in Kattegat. Such estimates are obviously of great biological interest, and even if only rough approximations are a valuable contribution to our understanding of the metabolism of the sea and of the possibility of increasing the yield of local fisheries.

But on studying these Danish results in the light of what we know of our own marine fauna, although none of our seas has been examined in the same detail by the bottom-sampler method, it seems probable that the animal communities as defined by Petersen are not exactly applicable on our coasts and that the estimates of relative and absolute abundance may be very different in different seas under different conditions. The work will have to be done in each great area, such as the North Sea, the English Channel, and the Irish Sea, independently. This is a necessary investigation, both biological and physical,

[4] See *Reports of the Danish Biological Station*, and especially the *Report* for 1918 "The Sea Bottom and its Production of Fish Food."

which lies before the oceanographers of the future, upon the results of which the future preservation and further cultivation of our national sea-fisheries may depend.

It has been shown by Johnstone and others that the common edible animals of the shore may exist in such abundance that an area of the sea may be more productive of food for man than a similar area of pasture or crops on land. A Lancashire mussel bed has been shown to have as many as 16,000 young mussels per square foot, and it is estimated that in the shallow waters of Liverpool Bay there are from twenty to 200 animals of sizes varying from an amphipod to a plaice on each square meter of the bottom.[5]

From these and similar data which can be readily obtained, it is not difficult to calculate totals by estimating the number of square yards in areas of similar character between tide-marks or in shallow water. And from weighings of samples some approximation to the number of tons of available food may be computed. But one must not go too far. Let all the figures be based upon actual observation. Imagination is necessary in science, but in calculating a population of even a very limited area it is best to believe only what one can see and measure.

Countings and weighings. however, do not give us all the information we need. It is something to know even approximately the number of millions of animals on a mile of shore and the number of millions of tons of possible food in a sea-area, but that is not sufficient. All food-fishes are not equally nourishing to man, and all plankton and bottom invertebrata are not equally nourishing to a fish. At this point the biologist requires the assistance of the physiologist and the bio-chemist. We want to know next the value of our food matters in proteids, carbohydrates, and fats, and the resulting calories. Dr. Johnstone, of the oceanography department of the University of Liverpool, has already shown us how markedly a fat summer herring differs in essential constitution from the ordinary white fish, such as the cod, which is almost destitute of fat.

Professor Brandt, at Kiel, Professor Benjamin Moore, at Port Erin, and others have similarly shown that plankton gatherings may vary greatly in their nutrient value according as they are composed mainly of Diatoms, of Dinoflagellates, or of Copepoda. And, no doubt, the animals of the "benthos," the common invertebrates of our shores, will show similar differ-

[5] "Conditions of Life in the Sea," Cambridge Univ. Press, 1908.

ences in analysis.[6] It is obvious that some contain more solid flesh, others more water in their tissues, others more calcareous matter in the exoskeleton, and that therefore weight for weight we may be sure that some are more nutritious than the others; and this is probably at least one cause of that preference we see in some of our bottom-feeding fish for certain kinds of food, such as polychæt worms, in which there is relatively little waste, and thin-shelled lamellibranch molluscs, such as young mussels, which have a highly nutrient body in a comparatively thin and brittle shell.

My object in referring to these still incomplete investigations is to direct attention to what seems a natural and useful extension of faunistic work, for the purpose of obtaining some approximation to a quantitative estimate of the more important animals of our shores and shallow water and their relative values as either the immediate or the ultimate food of marketable fishes.

Each such fish has its "food-chain" or series of alternative chains, leading back from the food of man to the invertebrates upon which it preys and then to the food of these, and so down to the smallest and simplest organisms in the sea, and each such chain must have all its links fully worked out as to seasonal and quantitative occurrence back to the Diatoms and Flagellates which depend upon physical conditions and take us beyond the range of biology—but not beyond that of oceanography. The Diatoms and the Flagellates are probably more important than the more obvious sea-weeds not only as food, but also in supplying to the water the oxygen necessary for the respiration of living protoplasm. Our object must be to estimate the rate of production and rate of destruction of all organic substances in the sea.

To attain to an approximate census and valuation of the sea—remote though it may seem—is a great aim, but it is not sufficient. We want not only to observe and to count natural objects, but also to understand them. We require to know not merely what an organism is—in the fullest detail of structure and development and affinities—and also where it occurs—again in full detail—and in what abundance under different circumstances, but also *how* it lives and what all its relations are to

[6] Moore and others have made analyses of the protein, fat, etc., in the soft parts of Sponge, Ascidian, Aplysia, Fusus, Echinus and Cancer at Port Erin, and find considerable differences—the protein ranging, for example, from 8 to 51 per cent., and the fat from 2 to 14 per cent. (see *Bio-Chemical Journ.*, VI., p. 291).

both its physical and its biological environment, and that is where the physiologist, and especially the bio-chemist, can help us. In the best interests of biological progress the day of the naturalist who merely collects, the day of the anatomist and histologist who merely describe, is over, and the future is with the observer and the experimenter animated by a divine curiosity to enter into the life of the organism and understand how it lives and moves and has its being. "Happy indeed is he who has been able to discover the causes of things."

Cardiff is a sea-port, and a great sea-port, and the Bristol Channel is a notable sea-fisheries center of growing importance. The explorers and merchant venturers of the southwest of England are celebrated in history. What are you doing now in Cardiff to advance our knowledge of the ocean? You have here an important university center and a great modern national museum, and either or both of these homes of research might do well to establish an oceanographical department, which would be an added glory to your city and of practical utility to the country. This is the obvious center in Wales for a sea-fisheries institute for both research and education. Many important local movements have arisen from British Association meetings, and if such a notable scientific development were to result from the Cardiff meeting of 1920, all who value the advance of knowledge and the application of knowledge to industry would applaud your enlightened action.

But in a wider sense, it is not to the people of Cardiff alone that I appeal, but to the whole population of these Islands, a maritime people who owe everything to the sea. I urge them to become better informed in regard to our national sea-fisheries and take a more enlightened interest in the basal principles that underlie a rational regulation and exploitation of these important industries. National efficiency depends to a very great extent upon the degree in which scientific results and methods are appreciated by the people and scientific investigation is promoted by the government and other administrative authorities. The principles and discoveries of science apply to aquiculture no less than to agriculture. To increase the harvest of the sea the fisheries must be continuously investigated, and such cultivation as is possible must be applied, and all this is clearly a natural application of the biological and hydrographical work now united under the science of oceanography.

THE INTERNAL CONSTITUTION OF THE STARS

By Professor A. S. EDDINGTON
PRESIDENT OF THE MATHEMATICAL AND PHYSICAL SCIENCE SECTION

THERE is another line of astronomical evidence which appears to show more definitely that the evolution of the stars proceeds far more slowly than the contraction hypothesis allows; and perhaps it may ultimately enable us to measure the true rate of progress. There are certain stars, known as Cepheid variables, which undergo a regular fluctuation of light of a characteristic kind, generally with a period of a few days. This light change is *not* due to eclipse. Moreover, the color quality of the light changes between maximum and minimum, evidently pointing to a periodic change in the physical condition of the star. Although these objects were formerly thought to be double stars, it now seems clear that this was a misinterpretation of the spectroscopic evidence. There is in fact no room for the hypothetical companion star; the orbit is so small that we should have to place it inside the principal star. Everything points to the period of the light pulsation being something intrinsic in the star; and the hypothesis advocated by Shapley, that it represents a mechanical pulsation of the star, seems to be the most plausible. I have already mentioned that the observed period does in fact agree with the calculated period of mechanical pulsation, so that the pulsation explanation survives one fairly stringent test. But whatever the cause of the variability, whether pulsation or rotation, provided only that it is intrinsic in the star, and not forced from outside, the density must be the leading factor in determining the period. If the star is contracting so that its density changes appreciably, the period can not remain constant. Now, on the contraction hypothesis the change of density must amount to at least 1 per cent. in 40 years. (I give the figures for δ Cephei, the best-known variable of this class.) The corresponding change of period should be very easily detectable. For δ Cephei the period ought to decrease 40 seconds annually.

Now δ Cephei has been under careful observation since 1785, and it is known that the change of period, if any, must be very small. S. Chandler found a decrease of period of $1/20$ second per annum, and in a recent investigation E. Hertzsprung has found a decrease of $1/10$ second per annum. The evidence that there is any decrease at all rests almost entirely on the earliest obser-

vations made before 1800, so that it is not very certain; but in any case the evolution is proceeding at not more than $\frac{1}{400}$ of the rate required by the contraction hypothesis. There must at this stage of the evolution of the star be some other source of energy which prolongs the life of the star 400-fold. The time-scale so enlarged would suffice for practically all reasonable demands.

I hope the dilemma is plain. Either we must admit that whilst the density changes 1 per cent. a certain period intrinsic in the star can change no more than $\frac{1}{800}$ of 1 per cent., or we must give up the contraction hypothesis.

If the contraction theory were proposed today as a novel hypothesis I do not think it would stand the smallest chance of acceptance. From all sides—biology, geology, physics, astronomy—it would be objected that the suggested source of energy was hopelessly inadequate to provide the heat spent during the necessary time of evolution; and, so far as it is possible to interpret observational evidence confidently, the theory would be held to be definitely negatived. Only the inertia of tradition keeps the contraction hypothesis alive—or rather, not alive, but an unburied corpse. But if we decided to inter the corpse, let us frankly recognize the position in which we are left. A star is drawing on some vast reservoir of energy by means unknown to us. This reservoir can scarcely be other than the sub-atomic energy which, it is known, exists abundantly in all matter; we sometimes dream that man will one day learn how to release it and use it for his service. The store is well-nigh inexhaustible, if only it could be tapped. There is sufficient in the sun to maintain its output of heat for 15 billion years.

Certain physical investigations in the past year, which I hope we may hear about at this meeting, make it probable to my mind that some portion of this sub-atomic energy is actually being set free in the stars. F. W. Aston's experiments seem to leave no room for doubt that all the elements are constituted out of hydrogen atoms bound together with negative electrons. The nucleus of the helium atom, for example, consists of 4 hydrogen atoms bound with 2 electrons. But Aston has further shown conclusively that the mass of the helium atom is less than the sum of the masses of the 4 hydrogen atoms which enter into it; and in this at any rate the chemists agree with him. There is a loss of mass in the synthesis amounting to about 1 part in 120, the atomic weight of hydrogen being 1.008 and that of helium just 4. I will not dwell on his beautiful proof of this, as you will no doubt be able to hear it from himself. Now

mass can not be annihilated, and the deficit can only represent the mass of the electrical energy set free in the transmutation. We can therefore at once calculate the quantity of energy liberated when helium is made out of hydrogen. If 5 per cent. of a star's mass consists initially of hydrogen atoms, which are gradually being combined to form more complex elements, the total heat liberated will more than suffice for our demands, and we need look no further for the source of a star's energy.

But is it possible to admit that such a transmutation is occurring? It is difficult to assert, but perhaps more difficult to deny, that this is going on. Sir Ernest Rutherford has recently been breaking down the atoms of oxygen and nitrogen, driving out an isotope of helium from them; and what is possible in the Cavendish laboratory may not be too difficult in the sun. I think that the suspicion has been generally entertained that the stars are the crucibles in which the lighter atoms which abound in the nebulæ are compounded into more complex elements. In the stars matter has its preliminary brewing to prepare the greater variety of elements which are needed for a world of life. The radio-active elements must have been formed at no very distant date; and their synthesis, unlike the generation of helium from hydrogen, is endothermic. If combinations requiring the addition of energy can occur in the stars, combinations which liberate energy ought not to be impossible.

We need not bind ourselves to the formation of helium from hydrogen as the sole reaction which supplies the energy, although it would seem that the further stages in building up the elements involve much less liberation, and sometimes even absorption, of energy. It is a question of accurate measurement of the deviations of atomic weights from integers, and up to the present hydrogen is the only element for which Mr. Aston has been able to detect the deviation. No doubt we shall learn more about the possibilities in due time. The position may be summarized in these terms: the atoms of all elements are built of hydrogen atoms bound together, and presumably have at one time been formed from hydrogen; the interior of a star seems as likely a place as any for the evolution to have occurred; whenever it did occur a great amount of energy must have been set free; in a star a vast quantity of energy is being set free which is hitherto unaccounted for. You may draw a conclusion if you like.

If, indeed, the sub-atomic energy in the stars is being freely used to maintain their great furnaces, it seems to bring a little nearer to fulfilment our dream of controlling this latent power for the well-being of the human race—or for its suicide.

So far as the immediate needs of astronomy are concerned, it is not of any great consequence whether in this suggestion we have actually laid a finger on the true source of the heat. It is sufficient if the discussion opens our eyes to the wider possibilities. We can get rid of the obsession that there is no other conceivable supply besides contraction, but we need not again cramp ourselves by adopting prematurely what is perhaps a still wilder guess. Rather we should admit that the source is not certainly known, and seek for any possible astronomical evidence which may help to define its necessary character. One piece of evidence of this kind may be worth mentioning. It seems clear that it must be the high temperature inside the stars which determines the liberation of energy, as H. N. Russell has pointed out. If so the supply may come mainly from the hottest region at the center. I have already stated that the general uniformity of the opacity of the stars is much more easily intelligible if it depends on scattering rather than on true absorption; but it did not seem possible to reconcile the deduced stellar opacity with the theoretical scattering coefficient. Within reasonable limits it makes no great difference in our calculations at what parts of the star the heat energy is supplied, and it was assumed that it comes more or less evenly from all parts, as would be the case on the contraction theory. The possibility was scarcely contemplated that the energy is supplied entirely in a restricted region round the center. Now, the more concentrated the supply, the lower is the opacity requisite to account for the observed radiation. I have not made any detailed calculations, but it seems possible that for a sufficiently concentrated source the deduced and the theoretical coefficients could be made to agree, and there does not seem to be any other way of accomplishing this. Conversely, we might perhaps argue that the present discrepancy of the coefficients shows that the energy supply is not spread out in the way required by the contraction hypothesis, but belongs to some new source only available at the hottest, central part of the star.

I should not be surprised if it is whispered that this address has at times verged on being a little bit speculative; perhaps some outspoken friend may bluntly say that it has been highly speculative from beginning to end. I wonder what is the touchstone by which we may test the legitimate development of scientific theory and reject the idly speculative. We all know of theories which the scientific mind instinctively rejects as fruitless guesses; but it is difficult to specify their exact defect or to supply a rule which will show us when we ourselves do err.

It is often supposed that to speculate and to make hypotheses are the same thing; but more often they are opposed. It is when we let our thoughts stray outside venerable, but sometimes insecure, hypotheses that we are said to speculate. Hypothesis limits speculation. Moreover, distrust of speculation often serves as a cover for loose thinking; wild ideas take anchorage in our minds and influence our outlook; whilst it is considered too speculative to subject them to the scientific scrutiny which would exorcise them.

If we are not content with the dull accumulation of experimental facts, if we make any deductions or generalizations, if we seek for any theory to guide us, some degree of speculation can not be avoided. Some will prefer to take the interpretation which seems to be most immediately indicated and at once adopt that as a hypothesis; others will rather seek to explore and classify the widest possibilities which are not definitely inconsistent with the facts. Either choice has its dangers; the first may be too narrow a view and lead progress into a cul-de-sac; the second may be so broad that it is useless as a guide, and diverges indefinitely from experimental knowledge. When this last case happens, it must be concluded that the knowledge is not yet ripe for theoretical treatment and speculation is premature. The time when speculative theory and observational research may profitably go hand in hand is when the possibilities, or at any rate the probabilities, can be narrowed down by experiment, and the theory can indicate the tests by which the remaining wrong paths may be blocked up one by one.

The mathematical physicist is in a position of peculiar difficulty. He may work out the behavior of an ideal model of material with specifically defined properties, obeying mathematically exact laws, and so far his work is unimpeachable. It is no more speculative than the binomial theorem. But when he claims a serious interest for his toy, when he suggests that his model is like something going on in Nature, he inevitably begins to speculate. Is the actual body really like the ideal model? May not other unknown conditions intervene? He can not be sure, but he can not suppress the comparison; for it is by looking continually to Nature that he is guided in his choice of a subject. A common fault, to which he must often plead guilty, is to use for the comparison data over which the more experienced observer shakes his head; they are too insecure to build extensively upon. Yet even in this, theory may help observation by showing the kind of data which it is especially important to improve.

I think that the more idle kinds of speculation will be avoided if the investigation is conducted from the right point of view. When the properties of an ideal model have been worked out by rigorous mathematics, all the underlying assumptions being clearly understood, then it becomes possible to say that such and such properties and laws lead precisely to such and such effects. If any other disregarded factors are present, they should now betray themselves when a comparison is made with Nature. There is no need for disappointment at the failure of the model to give perfect agreement with observation; it has served its purpose, for it has distinguished what are the features of the actual phenomena which require new conditions for their explanation. A general preliminary agreement with observation is necessary, otherwise the model is hopeless; not that it is necessarily wrong so far as it goes, but it has evidently put the less essential properties foremost. We have been pulling at the wrong end of the tangle, which has to be unravelled by a different approach. But after a general agreement with observation is established, and the tangle begins to loosen, we should always make ready for the next knot. I suppose that the applied mathematician whose theory has just passed one still more stringent test by observation ought not to feel satisfaction, but rather disappointment—"Foiled again! This time I *had* hoped to find a discordance which would throw light on the points where my model could be improved." Perhaps that is a counsel of perfection; I own that I have never felt very keenly a disappointment of this kind.

Our model of Nature should not be like a building—a handsome structure for the populace to admire, until in the course of time some one takes away a corner stone and the edifice comes toppling down. It should be like an engine with movable parts. We need not fix the position of any one lever; that is to be adjusted from time to time as the latest observations indicate. The aim of the theorist is to know the train of wheels which the lever sets in motion—that binding of the parts which is the soul of the engine.

In ancient days two aviators procured to themselves wings. Dædalus flew safely through the middle air across the sea, and was duly honored on his landing. Young Icarus soared upwards towards the sun till the wax melted which bound his wings, and his flight ended in fiasco. In weighing their achievements perhaps there is something to be said for Icarus. The classic authorities tell us that he was only "doing a stunt," but I prefer to think of him as the man who certainly brought to

light a constructional defect in the flying machines of his day. So too in science. Cautious Dædalus will apply his theories where he feels most confident they will safely go; but by his excess of caution their hidden weaknesses can not be brought to light. Icarus will strain his theories to the breaking-point till the weak joints gape. For a spectacular stunt? Perhaps partly; he is often very human. But if he is not yet destined to reach the sun and solve for all time the riddle of its constitution, yet he may hope to learn from his journey some hints to build a better machine.

THE SCIENTIFIC STUDY OF ALLOYS

By C. T. HEYCOCK

PRESIDENT OF THE CHEMICAL SECTION

IN 1897 Neville and I determined the complete freezing-point curve of the copper-tin alloys, confirming and extending the work of Roberts-Austen, Stansfield, and Le Chatelier; but the real meaning of the curve remained as much of a mystery as ever. Early in 1900 Sir G. Stokes suggested to us that we should make a microscopic examination of a few bronzes as an aid to the interpretation of the singularities of the freezing-point curve. An account of this work, which occupied us for more than two years, was published as the Bakerian Lecture of the Royal Society in February, 1903. Whilst preparing a number of copper-tin alloys of known composition we were struck by the fact that the crystalline pattern which developed on the free surface of the slowly cooled alloys was entirely unlike the structure developed by polishing and etching sections cut from the interior; it therefore appeared probable that changes were going on within the alloys as they cooled. In the hope that, as Sorby had shown in the case of steel, we could stereotype or fix the change by sudden cooling, we melted small ingots of the copper in alloys and slowly cooled them to selected temperatures and then suddenly chilled them in water. The results of this treatment were communicated to the Royal Sosiety and published in the *Proceedings*, February, 1901.

To apply this method to a selected alloy we first determined its cooling curve by means of an automatic recorder, the curve usually showing several halts or steps in it. The temperature of the highest of these steps correponded with a point on the liquidus, *i. e.*, when solid first separated out from the molten

mass. To ascertain what occurred at the subsequent halts, ingots of the melted alloy were slowly cooled to within a few degrees above and below the halt and then chilled, with the result just seen on the screen.

The method of chilling also enabled us to fix, with some degree of accuracy, the position of points on the solidus. If an alloy, chilled when it is partly solid and partly liquid, is polished and etched, it will be seen to consist of large primary combs embedded in a matrix consisting of mother liquor, in which are disseminated numerous small combs, which we called "chilled primary." By repeating the process at successively lower and lower temperatures we obtained a point at which the chilled primary no longer formed, *i. e.*, the upper limit of the solidus.

Although we made but few determinations of the physical properties of the alloys, it is needless to say how much they vary with the temperature and with the rapidity with which they are heated or cooled.

From a consideration of the singularities in the liquidus curve, coupled with the microscopic examination of slowly cooled and chilled alloys, we were able to divide the copper-tin alloys into certain groups having special qualities. It would take far too long to discuss these divisions. In interpreting our result we were greatly assisted not only by the application of the phase rule, but also by the application of Roozeboom's theory of solid solution (unfortunately Professor Roozeboom's letters were destroyed by fire in June, 1910) and by the advice he kindly gave us. At the time the paper was published we expressly stated that we did not regard all our results as final, as much more work was required to clear up points still obscure. Other workers—Shepherd and Blough, Giolitti and Tavanti—have somewhat modified the diagram.

Neither Shepherd and Blough nor Hoyt have published the photomicrographs upon which their results are based, so that it is impossible to criticize their conclusions. Giolitti and Tavanti have published some microphotographs, from which it seems that they had not allowed sufficient time for equilibrium to be established. In this connection I must call attention to the excellent work of Haughton on the constitution of the alloys of copper and tin.[1] He investigated the alloys rich in tin, and illustrated his conclusions by singularly beautiful microphotographs, and has done much to clear up doubtful points in this region of the diagram. I have dwelt at some length on this work, for copper-tin is probably the first of the binary alloys on

[1] *Journ. Institute of Metals*, March, 1915.

which an attempt had been made to determine the changes which take place in passing from one pure constituent to the other. I would again call attention to the fact that without a working theory of solution the interpretation of the results would have been impossible.

Since 1900, many complete equilibrium diagrams have been published; amongst them may be mentioned the work of Rosenhain and Tucker on the lead-tin alloys,[2] in which they describe hitherto unsuspected changes on the lead rich side which go on when these alloys are at quite low temperatures, also the constitution of the alloys of aluminum and zinc; the work of Rosenhain and Archbutt,[3] and quite recently the excellent work of Vivian, on the alloys of tin and phosphorus, which has thrown an entirely new light on this difficult subject.

So far I have called attention to some of the difficulties encountered in the examination of binary alloys. When we come to ternary alloys the difficulties of carrying out an investigation are enormously increased, whilst with quaternary alloys they seem almost insurmountable; in the case of steels containing always six, and usually more, constituents, we can only hope to get information by purely empirical methods.

Large numbers of the elements and their compounds which originally were laboriously prepared and investigated in the laboratory and remained dormant as chemical curiosities for many years have, in the fulness of time, taken their places as important and, indeed, essential articles of commerce. Passing over the difficulties encountered by Davy in the preparation of metallic sodium and by Faraday in the production of benzene (both of which materials are manufactured in enormous quantities at the present time), I may remark that even during my own lifetime I have seen a vast number of substances transferred from the category of rare laboratory products to that which comprises materials of the utmost importance to the modern metallurgical industries. A few decades ago, aluminium, chromium, cerium, thorium, tungsten, manganese, magnesium, molybdenum, nickel, calcium and calcium carbide, carborundum, and acetylene, were unknown outside the chemical laboratory of the purely scientific investigator; today these elements, their compounds and alloys, are amongst the most valuable of our industrial metallic products. They are essential in the manufacture of high-speed steels, of armor plate, of filaments for the electric bulb lamp, of incandescent gas

[2] *Phil. Trans.*, 1908.
[3] *Phil. Trans.*, 1911.

mantles, and of countless other products of modern scientific industry.

All these metallic elements and compounds were discovered, and their industrial uses foreshadowed, during the course of the purely academic research work carried out in our universities and colleges; all have become the materials upon which great and lucrative industries have been built up. Although the scientific worker has certainly not exhibited any cupidity in the past—although he has been content to rejoice in his own contributions to knowledge, and to see great manufacturing enterprises founded upon his work—it is clear that the obligation revolves upon those who have reaped in the world's markets the fruit of scientific discovery to provide from their harvest the financial aid without which scientific research can not be continued.

The truth of this statement is well understood by those of our great industrial leaders who are engaged in translating the results of scientific research into technical practice. As evidence of this I may quote the magnificent donation of £210,000 by the British Oil Companies towards the endowment of the school of chemistry in the University of Cambridge, the noble bequest of the late Dr. Messel, one of the most enlightened of our technical chemists, for defraying the cost of scientific research, the gifts of the late Dr. Ludwig Mond towards the upkeep and expansion of the Royal Institution, one of the strongholds of British chemical research, and the financial support given by the Goldsmiths' and others of the great City of London Livery Companies (initiated largely by the late Sir Frederick Abel, Sir Frederick Bramwell, and Mr. George Matthey), to the foundation of the Imperial College of Science and Technology. The men who initiated these gifts have been themselves intimately associated with developments both in science and industry; they have understood that the field must be prepared before the crop can be reaped. Fortunately our great chemical industries are, for the most part, controlled and administered by men fully conversant with the mode in which technical progress and prosperity follow upon scientific achievement; and it is my pleasant duty to record that within the last few weeks the directors of one of our greatest chemical-manufacturing concerns have, with the consent of their shareholders, devoted £100,000 to research. Doubtless other chemical industries will in due course realize what they have to gain by an adequate appreciation of pure science.

If the effort now being made to establish a comprehensive

scheme for the resuscitation of chemical industry within our empire is to succeed, financial support on a very liberal scale must be forthcoming, from the industry itself, for the advancement of purely scientific research. This question has been treated recently in so able a fashion by Lord Moulton that nothing now remains but to await the results of his appeal for funds in aid of the advancement of pure science.

In order to prevent disappointment, and a possible reaction in the future, in those who endow pure research, it is necessary to give a word of warning. It must be remembered that the history of science abounds in illustrations of discoveries, regarded at the time as trivial, which have in after years become epoch-making.

In illustration I would cite Faraday's discovery of electromagnetic induction. He found that when a bar magnet was thrust into the core of a bobbin of insulated copper wire, whose terminals were connected with a galvanometer, a momentary current was produced; whilst on withdrawing the magnet a momentary reverse current occurred; a purely scientific experiment destined in later years to develop into the dynamo and with it the whole electrical industry. Another illustration may be given: Guyton de Morxeau, Northmore, Davy, Faraday and Cagniard Latour between 1800 and 1850 were engaged in liquefying many of the gases. Hydrogen, oxygen, nitrogen, marsh gas, carbon-monoxide, and nitric oxide, however, resisted all efforts, until the work of Joule and Andrews gave the clue to the causes of failure. Some thirty years later by careful application of the theoretical considerations all the gases were liquefied. The liquefaction of oxygen and nitrogen now forms the basis of a very large and important industry.

Such cases can be multiplied indefinitely in all branches of science.

Perhaps the most pressing need of the present day lies in the cultivation of a better understanding between our great masters of productive industry, the shareholders to whom they are in the first degree responsible, and our scientific workers; if, by reason of any turbidity of vision, our large manufacturing corporations fail to discern that, in their own interest, the financial support of purely scientific research should be one of their first cares, technical advance will slacken and other nations, adopting a more far-sighted policy, will forge ahead in science and technology. It should, I venture to think, be the bounden duty of every one who has at heart the aims and objects of the British Association to preach the doctrine that in closer

sympathy between all classes of productive labor, manual and intellectual, lies our only hope for the future. I can not do better than conclude by quoting the words of Pope, one of our most characteristically British poets:

> By mutual confidence and mutual aid
> Great deeds are done and great discoveries made.

WHERE DOES ZOOLOGY STAND?

By Professor J. STANLEY GARDINER

PRESIDENT OF THE ZOOLOGICAL SECTION

THE public has the right to consider and pass judgment on all that affects its civilization and advancement, and both of these largely depend on the position and advance of science. I ask its consideration of the science of zoology, whether or not it justifies its existence as such, and, if it does, what are its needs. It is at the parting of the ways. It either has to justify itself as a science or be altogether starved out by the new-found enthusiasm for chemistry and physics, due to the belief in their immediate application to industries.

It is a truism to point out that the recent developments in chemistry and physics depend, in the main, on the researches of men whose names are scarcely known to the public; this is equally true for all sciences. A list of past presidents of the Royal Society conveys nothing to the public compared with a list of captains of industry who, to do them justice, are the first to recognize that they owe their position and wealth to these scientists. These men of science are unknown to the public, not on account of the smallness of their discoveries, but rather on account of their magnitude, which makes them meaningless to the mass.

Great as have been the results in physical sciences applied to industry, the study of animal life can claim discoveries just as great. Their greatest value, however, lies not in the production of wealth, but rather in their broad applicability to human life. Man is an animal and he is subject to the same laws as other animals. He learns by the experience of his forebears, but he learns, also, by the consideration of other animals in relationship to their fellows and to the world at large. The whole idea of evolution, for instance, is of indescribable value; it permeates all life today; and yet Charles Darwin, whose researches did more than any others to establish its facts, is

too often only known to the public as "the man who said we came from monkeys."

Whilst first and foremost I would base my claim for the study of animal life on this consideration, we can not neglect the help it has given to the physical welfare of man's body. It is not out of place to draw attention to the manner in which pure zoological science has worked hand in hand with the science of medicine. Harvey's experimental discovery of the circulation of the blood laid the foundation for that real knowledge of the working of the human body which is at the basis of medicine; our experience of the history of its development gives us good grounds to hope that the work that is now being carried out by numerous researches under the term "experimental" will ultimately elevate the art of diagnosis into an exact science. Harvey's work, too, mostly on developing chicks, was the starting-point for our knowledge of human development and growth. Instances in medicine could be multiplied wherein clinical treatment has only been rendered possible by laborious research into the life histories of certain parasites preying often on man and other animals alternately. In this connection there seems reason at present for the belief that the great problem of medical science, cancer, will reach its solution from the zoological side. A pure zoologist has shown that typical cancer of the stomach of the rat can be produced by a parasitic threadworm (allied to that found in pork, Trichina), this having as a carrying host the American cockroach, brought over to the large warehouse of Copenhagen in sacks of sugar. Our attack on such parasites is only made effective by what we know of them in lower forms, which we can deal with at will. Millions of the best of our race owe their lives to the labors of forgotten men of science, who laid the foundations of our knowledge of the generations of insects and flat-worms, the modes of life of lice and ticks, and the physiology of such lowly creatures as *Amœba* and *Paramecium;* parasitic disease—malaria, Bilhaziasis, typhus, trench fever and dysentery—was as deadly a foe to us as was the Hun.

Of immense economic importance in the whole domain of domestic animals and plants was the rediscovery, early in the present century, of the completely forgotten work of Gregor Mendel on cross-breeding, made known to the pesent generation largely by the labors of a former president of this Association, who, true man of science, claims no credit for himself. We see results already in the few years that have elapsed in special breeds of wheat, in which have been combined with exactitude

the qualities man desires. The results are in the making—and this is true of all things in biology—but can any one doubt that the breeding of animals is becoming an exact science? We have got far, perhaps, but we want to get much further in our understanding of the laws governing human heredity; we have to establish immunity to disease. Without the purely scientific study of chromosomes (the bodies which carry the physical and mental characteristics of parents to children) we could have got nowhere, and to reach our goal we must know more of the various forces which in combination make up what we term life.

In agricultural sciences we are confronted with pests in half a dozen different groups of animals. We have often to discover which of two or more is the damaging form, and the difficulty is greater where the damage is due to association between plant and animal pests. Insects are, perhaps, the worst offenders, and our basal knowledge of them as living organisms—they can do no damage when dead, and perhaps pinned in our showcases—is due to Redi, Schwammerdam, and Réamur in the middle of the seventeenth century. Our present successful honey production is founded on the curiosity of these men in respect to the origin of life and the generations of insects. The fact that most of the dominant insects have a worm (caterpillar or maggot) stage of growth, often of far longer duration than that of the insects, has made systematic descriptive work on the relation of worm and insect of peculiar importance. I hesitate, however, to refer to catalogues in which perhaps a million different forms of adults and young are described. Nowadays we know, to a large degree, with what pests we deal and we are seeking remedies. We fumigate and we spray, spending millions of money, but the next remedy is in the use of free-living enemies or parasites to prey on the insect pests. The close correlation of anatomy with function is of use here in that life histories, whether parasitic, carnivorous, vegetarian, or saprophagous, can be foretold in fly maggots from the structure of the front part of their gut (pharynx); we know whether any maggot is a pest, is harmless, or is beneficial.

I won't disappoint those who expect me to refer more deeply to science in respect to fisheries, but its operations in this field are less known to the public at large. The opening up of our northwestern grounds and banks is due to the scientific curiosity of Wyville Thomson and his *confrères* as to the existence or non-existence of animal life in the deep sea. It was sheer desire for knowledge that attracted a host of inquirers to investigate the life history of river eels. The wonder of a fish

living in our shallowest pools and travelling two or three thousand miles to breed, very likely on the bottom in 2,000 fathoms, and subjected to pressures varying from 14 pounds to 2 tons per square inch, is peculiarly attractive. It shows its results in regular eel farming, the catching and transplantation of the baby eels out of the Severn into suitable waters, which can not, by the efforts of nature alone, be sure of their regular supply. Purely scientific observations on the life histories of flat fish—these were largely stimulated by the scentific curiosity induced by the views of Lamarck and Darwin as to the causes underlying their anatomical development—and on the feeding value and nature of Thisted Bredning and the Dogger Bank, led to the successful experiments on transplantation of young plaice to these grounds and the phenomenal growth results obtained, particularly on the latter. Who can doubt that this "movement of herds" is one of the first results to be applied in the farming of the North Sea as soon as the conservation of our fish supply becomes a question of necessity?

The abundance of mackerel is connected with the movements of Atlantic water into the British Channel and the North Sea, movements depending on complex astronomical, chemical, and physical conditions. They are further related to the food of the mackerel, smaller animal life which dwells only in these Atlantic waters. These depend, as indeed do all animals, on that living matter which possesses chlorophyll for its nutrition and which we call plant. In this case the plants are spores of algæ, diatoms, etc., and their abundance as food again depends on the amount of the light of the sun—the ultimate source, it might seem, of all life.

A method of ascertaining the age of fishes was sought purely to correlate age with growth in comparison with the growth of air-living vertebrates. This method was found in the rings of growth in the scales, and now the ascertaining of age-groups in herring shoals enables the Norwegian fisherman to know with certainty what possibilities and probabilities are before them in the forthcoming season. From the work on the blending together of Atlantic with Baltic and North Sea water off the Baltic Bight and of the subsequent movements of this Bank water, as it is termed, into the Swedish fiords can be understood, year by year, the Swedish herring fishery. It is interesting that these fisheries have been further correlated with cycles of sun spots, and also with longer cycles of lunar changes.

The mass of seemingly unproductive scientific inquiries undertaken by the United States Bureau of Fisheries, thirty to

fifty years ago, was the forerunner of their immense fish-hatching operations, whereby billions of fish eggs are stripped year by year and the fresh waters of that country made into an important source for the supply of food. The study of the growth stages of lobsters and crabs has resulted in sane regulations to protect the egg-carrying females, and in some keeping up of the supply in spite of the enormously increased demand. Lastly, the study of free-swimming larval stages in mollusca, stimulated immensely by their similarity to larval stages in worms and starfishes, has given rise to the establishment of a successful pearl-shell farm at Dongonab, in the Red Sea, and of numerous fresh-water mussel fisheries in the southern rivers of the United States, to supply small shirt buttons.

Fishery investigation was not originally directed to a more ambitious end than giving a reasonable answer to a question of the wisdom or unwisdom of compulsorily restricting commercial fishing, but it was soon found that this answer could not be obtained without the aid of pure zoology. The spread of trawling—and particularly the introduction of steam trawling during the last century—gave rise to grave fears that the stock of fish in home waters might be very seriously depleted by the use of new methods. We first required to know the life histories of the various trawled fish, and Sars and others told us that the eggs of the vast majority of the European marine food species were pelagic; in other words, that they floated, and thus could not be destroyed, as had been alleged. Trawl fishing might have to be regulated all the same, for there might be an insufficient number of parents to keep up the stock. It was clearly necessary to know the habits, movements, and distribution of the fishes, for all were not, throughout their life, or at all seasons, found on the grounds it was practicable to fish. A North Sea plaice of 12 in. in length, a quite moderate size, is usually five years old. The fact that of the female plaice captured in the White Sea, a virgin ground, the vast majority are mature, while less than half the plaice put upon our markets from certain parts of the southern North Sea in the years immediately before the war had ever spawned, is not only of great interest, but gives rise to grave fears as to the possibility of unrestricted fishing dangerously depleting the stock itself. There is, however, another group of ideas surrounding the question of getting the maximum amount of plaice-meat from the sea; it may be that the best size for catching is in reality below the smallest spawning size. I here merely emphasize that in the plaice we have an instance of an important food fish, whose

capture it will probably be necessary to regulate, and that in determining how best the stock may be conserved, what sizes should receive partial protection, on what grounds fish congregate and why, and in all the many cognate questions which arise, answers to either can only be given by the aid of zoological science.

But why multiply instances of the applications of zoology as a pure science to human affairs? Great results are asked for on every side of human activities. The zoologist, if he be given a chance to live and to hand on his knowledge and experience to a generation of pupils, can answer many of them. He is increasingly getting done with the collection of anatomical facts, and he is turning more and more to the why and how animals live. We may not know in our generation nor in many generations what life is, but we can know enough to control that life. The consideration of the fact that living matter and water are universally associated opens up high possibilities. The experimental reproduction of animals, without the interposition of the male, is immensely interesting; where it will lead no one can foretell. The association of growth with the acidity and alkalinity of the water is a matter of immediate practical importance, especially to fisheries. The probability of dissolved food material in sea and river water, independent of organized organic life and absorbable over the whole surfaces of animals, is clearly before us. It is possible that that dissolved material may be even now being created in nature without the assistance of organic life? The knowledge of the existence in food of vitamines, making digestible and usable what in food would otherwise be wasted, may well result in economics of food that will for generations prevent the necessity for the artificial restriction of populations. The parallel between these vitamines and something in sea-water may quite soon apply practically to the consideration of all life in the sea. Finally, what we know of the living matter of germ cells puts before us the not impossible hope that we may influence for the better the generations yet to come.

If it is the possibility in the unknown that makes a science, are there not enough possibilities here? Does zoology, with these problems before it, look like a decayed and worked-out science? Is it not worthy to be ranked with any other science, and is it not worthy of the highest support? Is it likely to show good value for the money spent upon it? Should we not demand for it a professorial chair in every university that wishes to be regarded as an educational institution? And has not the occu-

pant of such a chair a task at least equal in difficulty to that of the occupant of any other chair? Surely the zoologist may reasonably claim an equal position and pay to that of the devotee of any other science? The researcher is not a huckster and will not make this claim on his own behalf, but the occupant of this chair may be allowed to do so for him.

THE MAP OF EUROPE AFTER THE WAR

By JOHN McFARLANE, M.A.

PRESIDENT OF THE GEOGRAPHICAL SECTION

WHEN we turn to Austria we are confronted with the great tragedy in the reconstruction of Europe. Of that country it could once be said "Bella gerant alii, tu felix Austria nube," but today, when dynastic bonds have been loosened, the constituent parts of the great but heterogeneous empire which she thus built up have each gone its own way. And for that result Austria herself is to blame. She failed to realize that an empire such as hers could only be permanently retained on a basis of common political and economic interest. Instead of adopting such a policy, however, she exploited rather than developed the subject nationalities, and today their economic, no less than their political independence of her is vital to their existence. Thus it is that the Austrian capital, which occupies a situation unrivalled in Europe, and which before the war numbered over 2,000,000 souls, finds herself with her occupation gone. For the moment Vienna is not necessary either to Austria or to the so-called Succession States, and she will not be necessary to them until she again has definite functions to perform. I do not overlook the fact that Vienna is also an industrial city, and that it, as well as various other towns in Lower Austria, are at present unable to obtain either raw materials for their industries or foodstuffs for their inhabitants. But there are already indications that this state of affairs will shortly be ameliorated by economic treaties with the neighboring States. And what I am particularly concerned with is not the temporary but the permanent effects of the change which has taken place. The entire political re-orientation of Austria is necessary if she is to emerge successfully from her present trials, and such a re-orientation must be brought about with due regard to geographical and ethnical conditions. The two courses which are open to her lead in opposite directions. On

the one hand she may become a member of a Danubian confederation, on the other she may throw in her lot with the German people. The first would really imply an attempt to restore the economic position which she held before the war, but it is questionable whether it is either possible or expedient for her to make such an attempt. A Danubian confederation will inevitably be of slow growth, as it is only under the pressure of economic necessity that it will be joined by the various nationalities of southeastern Europe. The suggestions made by Mr. Asquith, Mr. Keynes, and others, for a compulsory free-trade union would, if carried into effect, be provocative of the most intense resentment among most, if not all, of the states concerned. But even if a Danubian confederation were established it does not follow that Austria would be able to play a part in it similar to that which she played in the Dual Monarchy. With the construction of new railways and the growth of new commercial centers it is probable that much of the trade with the southeast of Europe which formerly passed through Vienna will in future go to the east of that city. Even now Pressburg, or Bratislava, to give it the name by which it will hence be known, is rapidly developing at the expense alike of Vienna and Budapest. Finally, Austria has in the past shown little capacity to understand the Slav peoples, and in any case her position in what would primarily be a Slav confederation would be an invidious one. For these reasons we turn to the suggestion that Austria should enter the German Empire, which, both on geographical and on ethnical grounds, would appear to be her proper place. Geographically she is German, because the bulk of the territory left to her belongs either to the Alpine range or to the Alpine foreland. It is only when we reach the basin of Vienna that we leave the mid-world mountain system and look towards the southeast of Europe across the great Hungarian plain. Ethnically, of course, she is essentially German. Now although my argument hitherto has rather endeavored to show that the transfer of territory from one state to another on purely economic grounds is seldom to be justified, it is equally indefensible to argue that two states which are geographically and ethnically related are not to be allowed to unite their fortunes because it would be to their interest to do so. And that it would be to their interest there seems little doubt. Austria would still be able to derive some of her raw materials and foodstuffs from the Succession States, and she would have, in addition, a great German area in which she would find scope for her commercial and financial activities. Even if Naumann

were but playing the part of the Tempter, who said "All these things will I give thee if thou wilt fall down and worship me," he undoubtedly told the truth when he said:

> The whole of Germany is now more open to the Viennese crafts than ever before. The Viennese might make an artistic conquest extending to Hamburg and Danzig.

But not only would Austria find a market for her industrial products in Germany, she would become the great trading center between Germany and southeast Europe, and in that way would once more be, but in a newer and better sense than before, the *Ostmark* of the German people.

The absorption of Austria in Germany is opposed by France, mainly because she can not conceive that her great secular struggle with the people on the other side of the Rhine will ever come to an end, and she fears the addition of 6,500,000 to the population of her ancient enemy. But quite apart from the fact that Germany and Austria can not permanently be prevented from following a common destiny if they so desire, and apart from the fact that politically it is desirable they should do so with at least the tacit assent of the Allied Powers rather than in face of their avowed hostility, there are reasons for thinking that any danger to which France might be exposed by the additional man-power given to Germany would be more than compensated for by the altered political condition in Germany herself. Vienna would form an effective counterpoise to Berlin, and all the more so because she is a great geographical center, while Berlin is more or less a political creation. The South German people have never loved the latter city, and today they love her less than ever. In Vienna they would find not only a kindred civilization with which they would be in sympathy, but a political leadership to which they would readily give heed. In such a Germany, divided in its allegiance between Berlin and Vienna, Prussian animosity to France would be more or less neutralized. Nor would Germany suffer disproportionately to her gain, since in the intermingling of Northern efficiency with Southen culture she would find a remedy for much of the present discontents. When the time comes, and Austria seeks to ally herself with her kin, we hope that no impassable obstacle will be placed in her way.

The long and as yet unsettled controversy on the limits of the Italian Kingdom illustrates very well the difficulties which may arise when geographical and ethnical conditions are subordinated to considerations of military strategy, history, and senti-

ment in the determination of national boundaries. The annexation of the Alto Adige has been generally accepted as inevitable. It is true that the population is German, but here, as in Bohemia, geographical conditions appear to speak the final word. Strategically also the frontier is good, and will do much to allay Italian anxiety with regard to the future. Hence, although ethnical conditions are to some extent ignored, the settlement which has been made will probably be a lasting one.

On the east the natural frontier of Italy obviously runs across the uplands from some point near the eastern extremity of the Carnic Alps to the Adriatic. The pre-war frontier was unsatisfactory for one reason because it assigned to Austria the essentially Italian region of the lower Isonzo. But once the lowlands are left on the west the uplands which border them on the east, whether Alpine or Karst, mark the natural limits of the Italian Kingdom, and beyond a position on them for strategic reasons the Italians have no claims in this direction except what they can establish on ethnical grounds. To these, therefore, we turn. In Carniola the Slovenes are in a large majority, and in Gorizia they also form the bulk of the population. On the other hand, in the town and district of Trieste the Italians predominate, and they also form a solid block on the west coast of Istria, though the rest of that country is peopled mainly by Slovenes. It seems to follow, therefore, that the plains of the Isonzo, the district of Trieste, and the west coast of Istria, with as much of the neighboring upland as is necessary to secure their safety and communications, should be Italian and that the remainder should pass to the Jugo-Slavs. The so-called Wilson line, which runs from the neighborhood of Tarvis to the mouth of the Arsa, met these requirements fairly well, though it placed from 300,000 to 400,000 Jugo-Slavs under Italian rule, to less than 50,000 Italians, half of whom are in Fiume itself transferred to the Jugo-Slavs. Any additional territory must, by incorporating a larger alien element, be a source of weakness and not of strength to Italy. To Fiume the Italians have no claim beyond the fact that in the town itself they slightly outnumber the Croats, though in the double town of Fiume-Sushak there is a large Slav majority. Beyond the sentimental reasons which they urge in public, however, there is the economic argument, which, perhaps wisely, they keep in the background. So long as Trieste and Fiume belonged to the same empire the limits within which each operated were fairly well defined, but if Fiume become Jugo-Slav it will not only prove a serious rival to Trieste, but will prevent Italy

from exercising absolute control over much of the trade of Central Europe. For Trieste itself Italy has in truth little need, and the present condition of that city is eloquent testimony of the extent to which it depended for its prosperity upon the Austrian and German Empires. In the interests, then, not only of Jugo-Slavia but of Europe generally, Fiume must not become Italian, and the idea of constituting it a Free State might well be abandoned. Its development is more fully assured as the one great port of Jugo-Slavia than under any other form of government.

With regard to Italian claims in the Adriatic, little need be said. To the Dalmatian coast Italy has no right either on geographical or on ethnical grounds, and the possession of Pola, Valona, and some of the islands gives her all the strategic advantages which she has reason to demand. But, after all, the only danger which could threaten her in the Adiratic would come from Jugo-Slavia, and her best insurance against that danger would be an agreement by which the Adriatic should be neutralized. The destruction of the Austro-Hungarian fleet offers Italy a great opportunity of which she would do well to take advantage.

Of the prospects of Jugo-Slavia it is hard to speak with any feeling of certainty. With the exception of parts of Croatia-Slavonia and of Southern Hungary, the country is from the physical point of view essentially Balkan, and diversity rather than unity is its most pronounced characteristic. From this physical diversity there naturally results a diversity in outlook which might indeed be all to the good if the different parts of the country were linked together by a well-developed system of communication. Owing to the structure of the land, however, such a system will take long to complete.

Ethnic affinity forms the real basis of union, but whether that union implies unity is another matter. It is arguable that repulsion from the various peoples—Magyars, Turks, and Austrians—by whom they have been oppressed, rather than the attraction of kinship, is the force which has brought the Jugo-Slavs together. In any case the obstacles in the way of the growth of a strong national feeling are many. Serb, Croat, and Slovene, though they are all members of the Slav family, have each their distinctions and characteristics which political differences may tend to exaggerate rather than obliterate. In Serbian Macedonia, again, out of a total population of 1,100,000, there are 400,000 to 500,000 people who, though Slavs, are Bulgarian in their sympathies, and between Serb and Bulgarian

there will long be bitter enmity. Religious differences are not wanting. The Serbs belong to the Orthodox Church, but the Croats are Catholics, and in Bosnia there is a strong Mohammedan element. Cultural conditions show a wide range. The Macedonian Serb, who has but lately escaped from Turkish misrule, the untutored but independent Montenegrin, the Dalmatian, with his long traditions of Italian civilization, the Serb of the kingdom, a sturdy fighter but without great political insight, and the Croat and Slovene, whose intellectual superiority is generally admitted, all stand on different levels in the scale of civilization. To build up out of elements in many respects so diverse a common nationality without destroying what is best in each will be a long and laborious task. Economic conditions are not likely to be of much assistance. It is true that they are fairly uniform throughout Jugo-Slavia, and it is improbable that the economic interests of different regions will conflict to any great extent. On the other hand, since each region is more or less self-supporting, they will naturally unite into an economic whole less easily than if there had been greater diversity. What the future holds for Jugo-Slavia it is as yet impossible to say; but the country is one of great potentialities, and a long period of political rest might render possible the development of an important State.

This brings me to my conclusion. I have endeavored to consider the great changes which have been made in Europe not in regard to the extent to which they do or do not comply with the canons of boundary-making, for after all there are no frontiers in Europe which can in these days of modern warfare be considered as providing a sure defence, but in regard rather to the stability of the states concerned. A great experiment has been made in the new settlement of Europe, and an experiment which contains at least the germs of success. But in many ways it falls far short of perfection, and even if it were perfect it could not be permanent. The methods which ought to be adopted to render it more equable and to adapt it to changing needs it is not for us to discuss here. But as geographers engaged in the study of the ever-changing relations of man to his environment we can play an important part in the formation of that enlightened public opinion upon which alone a society of nations can be established.

THE ECONOMIC CONDITION OF EUROPE AFTER THE NAPOLEONIC WAR

By Dr. J. H. CLAPHAM, C.B.E., Litt.D.

PRESIDENT OF THE ECONOMIC SCIENCE AND STATISTICS SECTION

IN 1815 France had been engaged in almost continuous wars for twenty-three, England for twenty-two years. The German States had been at war less continuously; but they had been fought over, conquered, and occupied by the French. Prussia, for instance, was overthrown in 1806. When the final struggle against Napoleon began, in 1812, there was a French army of occupation of nearly 150,000 men in Prussia alone. From 1806 to 1814 Napoleon's attempt to exclude English trade from the Continent had led to the English blockade—with its striking resemblances to, and its striking differences from, the blockade of 1914–19. Warfare was less horribly intense, and so less economically destructive, than it has become in our day; but what it lacked in intensity it made up in duration.

Take, for instance, the loss of life. For England it was relatively small—because for us the wars were never people's wars. In France also it was relatively small in the earlier years, when armies of the old size were mainly employed. But under Napoleon it became enormous. Exact figures do not exist, but French statisticians are disposed to place the losses in the ten years that ended with Waterloo at fully 1,500,000. Some place them higher. As the population of France grew about 40 per cent. between 1805–15 and 1904–14, this would correspond to a loss of, say 2,100,000 on the population of 1914. The actual losses in 1914–18 are put at 1,370,000 killed and missing; and I believe these figures contain some colonial troops.

Or take the debts accumulated by victors and the requisitions or indemnities extorted from the vanquished. The wars of a century ago left the British debt at £848,000,000. According to our success or failure in securing repayment of loans made to Dominions and Allies, the Great War will have left us with a liability of from eight to nine times that amount. Whether our debt-carrying capacity is eight or nine times what it was a century ago may be doubted, and can not be accurately determined. But it is not, I would venture to say, less than six or seven time what it was, and it might well be more. A good deal depends on future price levels. At least the burdens are

comparable; and we understand better now where to look for broad shoulders to bear them.

After Waterloo France was called upon to pay a war indemnity of only £28,000,000, to be divided among all the victors. With this figure Prussia was thoroughly dissatisfied. Not, I think, without some reason. She reckoned that Napoleon had squeezed out of her alone, between 1806 and 1812, more than twice as much—a tremendous exaction, for she was in those days a very poor land of squires and peasants, whose treasury only received a few millions a year. England, who was mainly responsible—and that for sound political reasons—for the low figure demanded of France, found herself, the victor, in the curious position of being far more heavily burdened with debt than France, who had lost. England, of course, had acquired much colonial territory; but on the purely financial side the comparison between her and France was most unequal. England's total national debt in 1817 was £848,000,000. France's debt did not reach £200,000,000 until 1830.

The reasons why France came out of the wars so well financially were four. *First,* she had gone bankrupt during the Revolution, and had wiped out most of her old debt. *Second,* under Napoleon she had made war pay for itself, as the case of Prussia shows. *Third,* there was no financial operation known to the world in 1815 by which England's war debt, or even half of it, could have been transferred to France. *Fourth,* England never suggested any such transference, or, so far as I know, ever even discussed it.

France's financial comfort, immediately after her defeat, extended to her currency. During the Revolution she had made a classical experiment in the mismanagement of credit documents, with the assignats issued on the security of confiscated Church property; but after that she had put her currency in good order. Her final defeat in 1812–14, and again in 1815, did not seriously derange it. Indeed, the English currency was in worse order than the French, owing to the suspension of cash payments by the Bank of England; and so rapidly did France's credit recover after 1815 that in 1818 French 5 per cents. stood at almost exactly the present-day price of British 5 per cent. War Loan. That year she finished the payment of her war indemnity, and the last armies of occupation withdrew.

She had no doubt gained by waging war, and eventually suffering defeat, on foreign soil. No French city had been burnt like Moscow, stormed like Badajoz, or made the heart of a gigantic battle like Leipzig. Napoleon fought one brilliant

defensive campaign on French soil, in the valleys of the Marne and the Seine, in 1814. In 1815 his fate was decided in Belgium. Hardly a shot was fired in France; hardly a French cornfield was trampled down. But France, as in 1918, was terribly short of men, and, again, as in 1918, her means of communication had suffered. Napoleon's magnificent roads—he was among the greatest of road engineers—had gone out of repair; his great canal works had been suspended. These things, however, were soon set right by the government which followed him.

France's rapid recovery brings us to one of the essential differences between Western Europe a century ago and Western Europe to-day. In spite of Paris and her other great towns, the France of 1915 was a rural country, a land of peasants and small farmers. Only about 10 per cent. of her population lived in towns of 10,000 inhabitants or more. The town below 10,000, in all countries, is more often a rural market town, ultimately dependent on the prosperity of agriculture, than an industrial center. Parallels for France's condition must be sought to-day in Eastern Europe—in Serbia or Russia. It is a condition which makes the economics of demobilization easy. The young peasant goes back from the armies to relieve his father, his mother, and his sisters, who have kept the farm going. Moreover, France maintained a standing army of 240,000 men after 1815; and her losses in the Waterloo campaign had been so heavy that the actual numbers demobilized were relatively small. Demobilization left hardly a ripple of the surface of her economic life.

The German states were far more rural in character even than France. There were a few industrial districts, of a sort, in the West and in Saxony; a few trading towns of some size, like Hamburg and Frankfurt; but there was nowhere a city comparable to Paris. In 1819 the twenty-five cities which were to become in our day the greatest of the modern German Empire had not 1,250,000 inhabitants between them. Paris alone at that time had about 700,000. German statesmen, when peace came, were occupied not with problems arising from the situation of the urban wage-earner, though such problems existed, but with how to emancipate the peasants from the condition of semi-servility in which they had lived during the previous century. Here, too, demobilization presented few of the problems familiar to us. Probably not one man in ten demobilized was a pure wage-earner. The rest had links with the soil. The land, neglected during the war, was crying out for labor, and every

man had his place, even if it was a servile place, in rural society.

Things were different in England; but our demobilization problem was smaller than that of our Continental allies or enemies, who had mobilized national armies, though not of the modern size. On the other hand, we had kept an immense fleet in commission, the crews of which were rapidly discharged. Early in 1817 Lord Castlereagh stated in Parliament that 300,000 soldiers and sailors had been discharged since the peace. In proportion to population, that would be equivalent, for the whole United Kingdom, to nearly 750,000 to-day. For these men no provision whatever was made. They were simply thrown on the labor market; and the vast majority of them were ex-wage-earners or potential wage-earners, industrial, mercantile, or agricultural. The United Kingdom was not urbanized as it is to-day; but the census of 1821 showed that 21 per cent. of the population lived in cities of 20,000 inhabitants and upwards, and probably about 27 per cent. (as compared with France's 10 per cent.) lived in places of 10,000 and upwards. As industry in various forms, especially coal-mining, spinning, and weaving, was extensively carried on in rural or semi-rural districts, it is certain that at least one demobilized man of working age in every three was a potential wage-earner of industry or commerce. And as Great Britain had lost most of her peasant-holders, whether owners or small working farmers, the remainder of the demobilized rank and file were nearly all of the agricultural laborer class. They had to find employment; there was not a place in rural society waiting for them, as there was for the average French or German peasant soldier. It is not surprising that the years from 1815 to 1820 were, both economically and politically, probably the most wretched, difficult, and dangerous in modern English history.

Things were at their worst in 1816–17, both for England and for her continental neighbors. Western Europe was very near starvation. Had the harvest of 1815 not been excellent, so providing a carry-over of corn, or had the harvest of 1817 been much below the average, there must have been widespread disaster; so thorough and universal was the harvest failure of 1816. In the latter part of 1815 (December) wheat fell in England to 55*s.* 7*d.*, although no grain imports were allowed, except of oats. Early in 1816 the United Kingdom was actually exporting a little wheat. Then came a terrible spring—a long frost, snow lying about Edinburgh in May; all the rivers of Western Europe in flood. An equally disastrous summer followed. There was dearth, in places amounting to real famine,

everywhere—worst of all in Germany. Unlike France, the German states of a century ago were extraordinarily ill-provided with roads. What roads there were had gone to pieces in the wars. In winter even the mails could hardly get through with sixteen and twenty horses. Food supplies could not be moved over long distances by land; and the slightly more favored regions could not help the most unfortunate. There was a far wider gap between prices in Eastern and Western Germany in 1816 than there had been in the last bad famine year (1772). Each German state, in its anxiety, began to forbid export early in 1816, thus making things worse. At Frankfurt, the representatives of the German States, gathered for the Diet, could hardly feed their horses. Prices rose amazingly and quite irregularly, with the varying food conditions of the various provinces. In the spring of 1817 pallid half-starved people were wandering the fields, hunting for and grubbing up overlooked and rotten potatoes of the last year's crop.

In England the harvest failure of 1816 drove wheat up to 103*s*. 7*d*. a quarter for December of that year, and to 112*s*. 8*d*. for June of 1817. In Paris the June price in 1817 was equivalent to 122*s*. 5*d*. At Stuttgart the May price was equivalent to 138*s*. 7*d*. These are only samples. Think what these figures mean at a time when an English agricultural laborer's wage was about 9*s*. 6*d*., and a French or German unskilled wage far less. It must be recalled that there were no special currency causes of high prices either in France or Germany. These were real dearth prices. In the spring of '17 the French government was buying corn wherever it could find it—in England, North Africa, America—as another bad harvest was feared. Happily, the 1817 harvest was abundant, here and on the Continent. By September the Mark Lane price of wheat was 77*s*. 7*d*., and the Paris price 71*s*. 9*d*.

I have gone into price details for the purpose of drawing a contrast between a century ago and to-day. Except for the damage done to the German roads, the wars had very little to do with these food troubles of 1816–17. High and fluctuating food prices were the natural consequence of the general economic position of Western Europe a century ago. It was only in the most comfortable age in all history—the late nineteenth and early twentieth centuries—that low and stable food prices came to be regarded as normal. In the eighteenth century, when England fed herself and often had an exportable surplus, fluctuations were incessant. Take the ten years 1750–1760. The mean price of wheat at Eton in '52 was 45 per cent. above

the mean price in '50. The mean price in '57 was nearly 100 per cent. above the mean price of '50. On Lady Day '57 the price was 60*s*. 5¼*d*. On Lady Day '59 it was 37*s*. 4*d*. On Lady Day '61 it was 26*s*. 8*d*. The '61 mean price was exactly half the '57 mean price.

Eighteenth-century England was too well organized economically to be in much risk of actual famine, but for Ireland and large parts of the Continent famine was a normal risk. War and its effects had only accentuated, not created, that risk. Imports might reduce it, but could not avert it, because Western Europe tends to have approximately the same harvest conditions throughout, and it was impossible to draw really large supplementary supplies from anywhere else. So unimportant were overseas supplies that the Continent suffered very much more from the harvest failure of '16, in time of peace, than from the eight years' English blockade in time of war. If overseas supplies could be got they were hard to distribute, owing to defective transport facilities. Thanks to the work of the nineteenth century, the most terrific of all wars was required to bring Western Europe face to face with what had been both a war-time and a peace-time risk a century earlier.

THE STRENGTH OF MATERIALS IN AEROPLANE ENGINEERING

By Professor C. F. JENKIN, C.B.E., M.A.

PRESIDENT OF THE ENGINEERING SECTION

THE importance of research in all branches of industry is now becoming fully recognized. It is hardly necessary to point out the great possibilities of the Board of Scientific and Industrial Research, formed just before the war, or to lay stress on the attention which has been called to the need for research by events during the war. Probably in no branch of the Services was more research work done than in the Air Service, and the advances made in all directions in connection with flying were astonishing. My own work was confined to problems connected with materials of construction, and as a result of that work I have come to the conclusion that the time has come when the fundamental data on which the engineering theories of the strength and suitability of materials are based require thorough overhauling and revision. I believe that the present is a favorable time for this work, but I think that attention needs to be

drawn to it, lest research work is all diverted to the problems which attract more attention, owing to their being in the forefront of the advancing engineering knowledge, and lest the necessary drudgery is shirked in favor of the more exciting new discoveries.

It has been very remarkable how again and again in aeroplane engineering the problems to be solved have raised fundamental questions in the strength and properties of materials which had never been adequately solved. Some of these questions related to what may be termed theory, and some related to the physical properties of materials. I propose to-day to describe some of these problems, and to suggest the direction in which revision and extension of our fundamental theories and data are required and the lines on which research should be undertaken. Let us consider first one of the oldest materials of construction—timber. Timber was of prime importance in aircraft construction. The first peculiarity of this material which strikes us is that it is anisotropic. Its grain may be used to locate three principal axes—along the grain, radially across the grain, and tangentially across the grain. It is curious that there do not appear to be generally recognized terms for these three fundamental directions. A very few tests are sufficient to show that its strength is enormously greater along the grain than across it. How, then, is an engineer to calculate the strength of a wooden member? There is no theory, in a form available for the engineer, by which the strength of members made of an anisotropic material can be calculated.

I fancy I may be told that such a theory is not required—that experience shows that the ordinary theory is quite near enough. How utterly misleading such a statement is I will try to show by a few examples. Suppose a wooden tie or strut is cut from the tree obliquely so that the grain does not lie parallel to its length. In practice it is never possible to ensure that the grain is accurately parallel to the length of the member, and often the deviation is considerable. How much is the member weakened? This comparatively simple problem has been of immense importance in aeroplane construction, and, thanks to the researches made during the war, can be answered. The solution has thrown a flood of light on many failures which before were obscure. If the tensile strengths of a piece of timber are, say, 18,000 lb./sq. in. along the grain and 800 lb./sq. in. across it (radially or tangentially) and the shear strength is 900 lb./sq. in. along the grain—these figures correspond

roughly with the strengths of silver spruce—then if a tensile stress be applied at any angle to the grain the components of that stress in the principal directions must not exceed the above strengths, or failure will occur. Thus we can draw curves limiting the stress at any angle to the grain, and similar curves may be drawn for compression stresses. These theoretical curves have been checked experimentally, and the results of the tests confirm them closely except in one particular. The strengths at small inclination to the grain fall even faster than the theoretical curves would lead us to expect. The very rapid drop in strength for quite small deviations is most striking.

Similar curves have been prepared for tensile and compressive stresses inclined in each of the three principal planes for spruce, ash, walnut, and mahogany, so that the strengths of these timbers to resist forces in any direction can now be estimated reasonably accurately.

As a second example consider the strength of plywood. Plywood is the name given to wood built up of several thicknesses glued together with the grain in alternate thicknesses running along and across the plank. The result of this crossing of the grain is that the plywood has roughly equal strength along and across the plank. Plywood is generally built up of thin veneers, which are cut from the log by slicing them off as the log revolves in a lathe.

Owing to the taper in the trunk of the tree and to other irregularities in form, the grain in the veneer rarely runs parallel to the surface, but generally runs through the sheet at a more or less oblique angle. As a consequence the strength of plywood is very variable, and tests show that it is not possible to rely on its having more than half the strength it would have if the grain in the veneers were not oblique. It is therefore obviously possible to improve the manufacture enormously by using veneers *split off*, following the grain, in place of the present sliced veneers. The superiority of split or riven wood over cut wood has been recognized for ages. I believe all ladders and ladder rungs are riven. Hurdles, hoops, and laths are other examples. Knees in ships are chosen so that the grain follows the required outline.

Owing to the enormous difference in strength in timber along and across the grain, it is obviously important to get the grain in exactly the right direction to bear the loads it has to carry. The most perfect example I ever saw of building up a plywood structure to support all the loads on it was the frame of the German Schutte-Lanz airship, which was made entirely

of wood. At the complex junctions of the various girders and ties the wood, which was built up of very thin veneers—hardly thicker than plane shavings—layers were put on most ingeniously in the direction of every stress.

During the war I have had to reject numerous types of built-up struts intended for aeroplanes, because the grain of the wood was in the wrong direction to bear the load. The example shown—a McGruer strut—is one of the most elegant designs, using the grain correctly.

Many of the tests applied to timber are wrong in theory and consequently misleading. For example, the common method of determining Young's modulus for timber is to measure the elastic deflection of a beam loaded in the middle and to calculate the modulus by the ordinary theory, neglecting the deflection due to shear, which is legitimate in isotropic materials; but in timber the shear modulus is very small—for example, in spruce it is only about one sixtieth of Young's modulus—and consequently the shear deflection becomes quite appreciable, and the results obtained on test pieces of the common proportions lead to errors in the calculated Young's modulus of about 10 per cent.

The lantern plates show three standard tests; the first is supposed to give the shearing strength of the timber, but these test pieces fail by tension across the grain—not by shearing. Professor Robertson has shown that the true shear strength of spruce is about three times as great as the text-book figures, and has designed a test which gives fairly reliable results. The second figure represents a test intended to give the mean strength across the grain, but the concentration of stress at the grooves is so great that such test pieces fail under less than half the proper load. This fact was shown in a striking manner by narrowing a sample of this shape to half its width, when it actually bore a greater total load—*i. e.*, more than double the stress borne by the original sample. The third figure represents a test piece intended to measure the rather vague quality, "strength to resist splitting." The results actually depend on the tensile strength across the grain, on the elastic constants, and on the accidental position of the bottom of the groove relatively to the spring or autumn wood in the annular rings. Unless the theory is understood, rational tests can not be devised.

There are some valuable tropical timbers whose structure is far more complex than that of our ordinary northern woods. The grain in these timbers grows in alternating spirals—an arrangement which at first sight is almost incredible. The most

striking example of this type of wood I have seen is the Indian "Poon." The sample on the table has been split in a series of tangential planes at varying distances from the center of the tree, and it will be seen that the grain at one depth is growing in a right-hand spiral round the trunk; a little farther out it grows straight up the trunk; further out again it grows in a left-hand spiral, and this is repeated again and again, with a pitch of about two inches. The timber is strong and probably well adapted for use in large pieces—it somewhat resembles plywood—but it is doubtful whether it is safe in small pieces. No theory is yet available for estimating its strength, and very elaborate tests would be needed to determine its reliability in all positions. I had to reject it for aeroplanes during the war for want of accurate knowledge of its properties.

These examples show how necessary it is to have a theory for the strength of anisotropic materials before we can either understand the causes of their failure or make full use of their properties or even test them rationally.

The second material we shall consider is steel, and in dealing with it I do not wish to enter into any of the dozen or so burning questions which are so familiar to all metallurgists and engineers, but to call your attention to a few more fundamental questions. Steel is not strictly isotropic—but we may consider it to be so to-day. The first obvious question the engineer has to answer is, "What is its strength?" The usual tests give the ultimate strength, yield point, elastic limit, the elongation, the reduction of area, and perhaps the Brinell and Izod figures. On which of these figures is the dimension of an engine part, which is being designed, to be based? If we choose the ultimate strength we must divide it by a large factor of safety—a factor of ignorance. If we choose the yield point we must remember that none of the higher-grade steels have any yield point, and the nominal yield point depends on the fancy of the tester. This entirely imaginary point can not be used for accurate calculation except in a very few special cases. Can we base our calculation on the elongation—the reduction of area—the Izod test? If we face the question honestly we realize that there is no known connection between the test results and the stress we can safely call on the steel to bear. The only connecting link is that cloak for our ignorance—the factor of safety.

I feel confident that the only reliable property on which to base the strength of any engine part is the suitable *fatigue limit.* We have not yet reached the position of being able to specify this figure, but a considerable number of tests show that in

a wide range of steels (though there are some unexplained exceptions) the fatigue limit for equal $\pm$ stresses is a little under half the ultimate strength, and is independent of the elastic limit and nominal yield point, so that the ultimate strength may be replaced as the most reliable guide to true strength, with a factor—no longer of ignorance, but to give the fatigue limit—of a little over 2.

If the fatigue limit is accepted as the only sound basis for strength calculation for engine parts, and it is difficult to find any valid objection to it, then it is obvious that there is urgent need for extensive researches in fatigue, for the available data are most meager. The work is laborious, for there is not one fatigue limit, but a continuous series, as the signs and magnitudes of the stresses change. Many problems in connection with fatigue are of great importance and need much fuller investigation than they have so far received—*e. g.*, the effect of speed of testing; the effect of rest and heat treatment in restoring fatigued material; the effect of previous testing at higher or lower stresses on the apparent fatigue limit of a test piece. Some observers have found indications that the material may possibly be strengthened by subjecting it to an alternating stress below its fatigue limit, so that the results of fatigue tests may depend on whether the limit is approached by increasing the stress or by decreasing it.

Improved methods of testing are also needed—particularly methods which will give the results quickly. Stromeyer's method of measuring the first rise of temperature, which indicates that the fatigue limit is passed, as the alternating load is gradually increased, is most promising; it certainly will not give the true fatigue limit in all cases, for it has been shown by Bairstow that with some ranges of stress a finite extension occurs at the beginning of a test and then ceases, under stresses lower than the fatigue limit. But the fatigue limit in that case would not be a safe guide, for finite changes of shape are not permissible in most machines, so that in that case also Stromeyer's test may be exactly what is wanted. It can probably be simplified in detail and made practicable for commercial use. Better methods of testing in torsion are also urgently needed, none of those at present used being free from serious defects. Finally, there is a fascinating field for physical research in investigating the internal mechanism of fatigue failure.

JOHN TYNDALL (1820–1893)[1]

By Professor ARTHUR WHITMORE SMITH

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JOHN TYNDALL, British philosopher and physicist, was a most genial and interesting personality. In him a noble and generous nature was combined with a resolute will and lofty principles. He had a fine regard for the rights and feelings of others, and most of his controversies were in defense of truth and justice.

The great ideas of the conservation of energy and the mechanical equivalent of heat were novelties in his time, and his clear thinking and exposition did much to interpret the full significance of these laws. By the publication of his lectures in a style both clear and interesting, and expressed in non-technical language, he reached a large audience, and did more than any other person to secure the wide diffusion of these all-pervading truths that lie at the foundation of physical science.

In the Royal Society's catalogue of scientific papers 145 titles appear under Tyndall's name, and his more extensive writings comprise no less than 16 separate volumes. The complete story of a life so full can not be given in a single evening, and the mere reading of the titles of his many papers would occupy more time than is now allotted to me. But if we can catch a glimpse of his spirit, and gather a bit of inspiration from the enthusiasm with which he worked, this half hour will not be spent in vain.

John Tyndall was born near Carlow, in the southeastern part of Ireland, on the second of August, 1820. Originally of English descent, the Tyndalls crossed to Ireland in the seventeenth century. The elder John Tyndall, although poor, was a man of more than ordinary intellect, and he gave his son a good education in English and mathematics.

To a large extent, Tyndall was a self-made man. His mathematical training enabled him to enter the ordnance survey of Ireland at the age of nineteen, and because of his skill in drawing he was later selected for the English survey. For three years he was a civil engineer at Manchester, and during this

[1] An address delivered before the Research Club of the University of Michigan at a meeting commemorating the centenaries of John Tyndall and Herbert Spencer, 21 April, 1920.

time he spent much time in reading and in private study. It was partly through the reading of Carlyle that he was led to abandon the brilliant possibilities then open to a civil engineer, and devote his life to scientific study.

For some time he was connected with Queenwood College, in Hampshire County, where one of his duties was the instruction of a class in mathematics. His mind was ever on the alert to observe the natural phenomena of daily life, and his teaching was no mere following of text-book routine. It was his custom to give the boys their choice of following Euclid or trying problems of their own devising. The book was never chosen. Their diagrams were scratched on the walls and cut in the beams of the playground, thus showing the lively interest they took in the subject. They found it pleasant to prove by mathematics, and then verify by experiment, that the angular velocity of a reflected beam of light is twice that of the mirror from which it is reflected. And they were startled by the inference that if the earth turned seventeen times its actual speed all things at the equator would lose their weight and have the same tendency to fall upwards as downwards. The days spent with these boys made a deep impression upon Tyndall, and he looked forward to that future day when he might push these subjects a little further and add his own victories to the conquests already won.

The autumn of 1848 found him at Marburg, where, after two years of work, he received the degree of doctor of philosophy. His reputation as an investigator was established by the publication of his work on the magnetic properties of crystals, and the relation of magnetism and diamagnetism to molecular structure. The action of the atoms and molecules held an irresistible attraction for him and every investigation was conducted with molecular arrangement in mind. He was not satisfied with a few typical examples, but he examined nearly a hundred natural crystals and the entire collection of artificial crystals in the laboratory of Professor Bunsen. The subject was studied from every side until he had obtained a clear conception of all the conditions involved, and was able to formulate the general law.

Faraday had just published his researches on the behavior of crystals in taking a definite position when suspended between the poles of a strong magnet. "This force," he says, "appears to me to be very strange and striking in its character . . . for there is neither attraction nor repulsion."

It required long and patient effort to bring under the dominion of elementary principles the vast mass of facts which

experiments had brought to light, but the more he worked at the subject the more clearly did it appear to Tyndall that the action of crystals in the magnetic field was due, not to some new and unknown force, but to the modification of the known forces of magnetism and diamagnetism by the crystalline structure. It *was* true that the forces were neither attraction nor repulsion, taken singly, but it was *both,* thus producing a torque which turned the crystal into a determined position. The painstaking observations and the simply stated conclusion showed the qualities for which his work was ever distinguished.

Shortly after his return from Marburg he was appointed professor of physics in the Royal Institution, where Faraday was then director. Seldom have two men worked together so harmoniously as did Tyndall and Faraday during the years that followed. Their relationship from first to last was like that of father and son, and when Faraday died, fourteen years later, Tyndall succeeded him as director of the Royal Institution.

It was at this time also that he became acquainted with Spencer, who was about his own age, and with Huxley who was five years younger. This was the beginning of the most intimate of friendships. On all sorts of minor topics they were liable to differ in opinion, and they never hesitated to criticize each other; but the fundamental harmony between them was profound, for each cared immeasurably more for truth than for anything else. It was no small factor in his life for Tyndall to enjoy the friendship of these two men.

Not all of the investigations of Tyndall were carried out in the laboratory, for he was always awake to the events of daily experience. Even the "spirits" did not escape his observation, and it is especially interesting at this time to read of Tyndall's experience in this field.

The spirits themselves named the time and place of meeting, which proved to be a dinner at a private residence near London. The medium—a delicate looking young lady—was seated next to Tyndall. He records a bit of the conversation. He asked the young lady if she could see the curious things he had heard about—the light emitted by crystals, for example. "Oh, yes," she replied, "but I see light around all bodies."

T. "Even in perfect darkness?"

Med. "Yes; I see luminous atmospheres round all people. The atmosphere which surrounds Mr. C. would fill this room with light."

T. "You are aware of the effects ascribed to magnets?"

Med. "Yes; but a magnet makes me terribly ill."

T. "Am I to understand that, if this room were perfectly dark, you could tell whether it contained a magnet, without being informed of the fact?"

Med. "I should know of its presence on entering the room."

T. "How?"

Med. "I should be rendered instantly ill."

T. "How do you feel to-day?"

Med. "Particularly well; I have not been so well for months."

All the while there was in Tyndall's pocket, within six inches of her, a magnet; but he felt that nothing would be gained by showing it.

On the whole the evening was a dull one, but towards the end the spirits were asked to spell the name by which Tyndall was known in the spirit world. As the alphabet was slowly repeated a knock was heard when the letter P was reached. Beginning again, the letter O was knocked down. The next letter was E.

The knocks seemed to come from under the table, and Tyndall asked permission to go underneath to assure himself of the origin of the sounds. He remained under that table for a quarter of an hour, and was sure that no sound could be produced without his being able to locate its source. The spirits were urged and entreated to finish the word, but they had become dumb, and could spell no more. Tyndall then returned to his chair, but not without a feeling of despair regarding the prospects of humanity, never before experienced.

The spirits, however, resumed their spelling, and dubbed him, "Poet of Science." More than once after this he accepted invitations to be with the spirits. His comment is, "they do not improve on acquaintance. Surely no baser delusion ever obtained dominance over the weak mind of man."

In the autumn of 1854 Tyndall attended a meeting of the British Association at Liverpool, and at its close he took the opportunity to visit North Wales, where he saw the slate quarries. It interested him to see how readily the rock split open in parallel planes, like wood before an axe. The explanation that these were the layers in which the material was deposited did not satisfy him. Consultation with geologists showed him that the planes of cleavage were not those of stratification, and further investigation on numerous substances convinced him that the cleavage was caused by the effects of pressure.

Two years later these phenomena were made the subject of a lecture at the Royal Institution. His friend Huxley was

present, and suggested that this aspect of slaty cleavage might have some bearing on the laminated structure of glacier ice. They were both going to Switzerland that summer, and they arranged a joint excursion over some of the famous glaciers, where they could observe together the veined structure of the ice.

No man knows, when he commences the examination of a physical problem, where it will lead him. For Tyndall this was the beginning of many visits to the Alps, where he continued the study of glaciers for many summers. He satisfied himself that the veined structure was due to pressure, but he was especially interested in learning how a crystalline solid like ice could flow like a liquid. He pointed out the inadequacy of earlier theories, and showed by experimental demonstration that the flow was due to continued minute fracture and subsequent refreezing of the ice.

But once in Switzerland, the fascination of the mountains claimed him, and he became an Alpine enthusiast. Summer after summer he returned to conquer some untrodden Alp, or continue an unfinished investigation. The ascent of Mont Blanc was not complete without planting thermometers at several stations to record the cold of winter while he was absent. Nor was science alone to benefit from these excursions. The volumes that record his experiences are gems of literature, pervaded from cover to cover with the vigor and freshness of the Alpine air.

Tyndall always considered original investigation to be the great object of his life, and his most extensive researches are those in the domain of radiant heat. These experiments were stimulated by the conviction that not only the physical, but also the molecular, condition of bodies probably played a very important part in the phenomena of the radiation and absorption of heat. He wanted to show the physical significance of an atomic theory which had been founded on purely chemical considerations, and this object was continually kept in mind. Radiant heat was used as an instrument to explore molecular condition, and to bring clearly into view the astonishing change in physical properties when the atoms of simple gases unite to form more complex combinations.

As new advance often awaits the production of new instruments, so Tyndall's first requirement was a galvanometer of increased sensitiveness. Having made this galvanometer, and also a sensitive thermo-pile, he proceeded to examine the absorption of radiant heat by various gases. The gas to be examined

was placed in a long tube, closed at each end with windows of rock salt. The source of heat was a copper cube filled with hot water. The heat radiating from this copper box passed through the gas in the tube and fell upon the thermopile placed just outside the farther window. The other face of the thermo-pile was warmed from a second source, similar to the first. When the tube was empty, the galvanometer pointed to zero. When the tube was filled with gas, if the molecules possessed any power of intercepting the heat waves, that side of the thermo-pile would receive less heat, and the galvanometer would show a deflection corresponding to the amount of heat thus absorbed by the gas.

Examined in this manner, dry air, oxygen, nitrogen, and hydrogen showed a very slight absorption of the radiant heat. But when in chemical combination, the astonishing fact appeared that carbon dioxide absorbed nearly 1,000 times as much as dry air. Nitric oxide absorbed 1,600 times as much as either nitrogen or oxygen. And ammonia absorbed 5,500 times as much as either of its constituents. To make sure that these results were real, and that errors in the method of observation, or impurities in the gases used, did not mask the true effects, required some thousands of experiments. Observations were repeated again and again, and under various conditions, until he was thoroughly familiar with all the factors that could affect the result. And conclusions were not published until the experiments had convinced him that they were correct.

The case of aqueous vapor in the air proved so interesting and important that a special series of experiments was made upon it. Not only was the air of London examined, but to avoid possible errors due to the effect of local impurities, air was brought from the country and from the seashore. This air, containing the normal amount of aqueous vapor, absorbed 70 times as much heat as air from which the moisture had been removed.

The importance of these results are manifest when they are stated in a different way. It appears from this that the aqueous vapor which exists within ten feet of the earth's surface on a day of moderate humidity is sufficient to absorb 10 per cent. of the entire terrestrial radiation, a considerable portion of which is thus returned to the earth. He thus explained the burning heat by day, followed by the enormous chilling at night, in those places that are not protected by a blanket of moist air. In a general way, this has been referred to the purity of the air, but this purity consists in the absence of the transparent

vapor, rather than that of smoke or other visible constituent.

Thus a comparatively slight change in the variable constituents of the atmosphere, by permitting free access of solar heat to the earth and checking the outflow of terrestrial heat into space, might produce changes of climate as great as those which the discoveries of geology reveal.

An extension of this inquiry led him to investigate the absorption of heat by various liquids and their vapors. The behavior of these vapors placed them in a definite order of relative absorption. For heat of the same quality, and using equivalent amounts of the different liquids, he proved that the liquids occupied the same order as their vapors. This led him to the conclusion that the act of absorption is molecular, and that the molecule maintains its power as an absorber and radiator in spite of its change from liquid to vapor. Later he considered this action as due, in large part, to the atoms composing the molecule, rather than its being solely a property of the molecule as a whole.

In another series of experiments the source of radiant heat was a flame of burning gas. The radiation from the hydrogen flame possessed a peculiar interest, for he thought it likely that the resonance between its periods of vibration and those of the cool aqueous vapor of the air might be such as to cause the atmospheric vapor to exert a special absorbent power.

His surmise in this respect was justified, for he found that 20 per cent. of the total radiation from the hydrogen flame was absorbed by 50 inches of *undried* air, whereas only about 6 per cent. of the radiation from a hot platinum spiral wàs thus absorbed. Nor was this resonance confined to aqueous vapor. The dried air, which was now transparent to the hydrogen flame, was able to absorb 14 per cent. of the heat from a flame of carbon monoxide. Air from the lungs, with the moisture removed, was able to intercept 50 per cent. of the entire radiation from the carbon monoxide flame.

As a result of these investigations, carried out with extreme care and in great detail, he showed the very intimate relation between the absorption of heat and the molecular condition of the absorbing body.

In connection with these experiments, he also showed that those bodies that were the most efficient absorbers of radiant heat were likewise the best radiators of that same heat.

But while we are greatly indebted to Tyndall for the new knowledge which he discovered in the domains of heat and other branches of physics, his name will continue to be loved and re-

membered even more for the interesting lectures in which his methods of research were explained to public audiences, and the fundamental principles of science made clear to them.

It must have been a delight to listen to him. He was famed for the charm and animation of his language, for lucidity of exposition, and singular skill in devising and conducting experimental illustrations. Both he and his younger friend Huxley were popular with the London audiences, but they were very different. Huxley convinced his audience and compelled their assent; Tyndall carried them with him. They could not help agreeing with Huxley even if they did not wish to do so; they wished to agree with Tyndall if they could. It was the aim of Tyndall to rise to the level of his subject from a basis so elementary that every one in his audience could comprehend it, and then to lead them on by experimental demonstrations to a more complete understanding of the truths of Nature.

In the autumn of 1872 he came to America, where, in several of the eastern cities, he delivered a series of lectures on "Light." His success as a lecturer was complete. At first he was somewhat in doubt regarding the intellectual level that might be expected of the audiences, but he received early warning to talk the same as he would at the Royal Institution. One who heard him says: "It was a rare treat to hear him lecture. His illustrative experiments were beautifully done, his speech was easy and eloquent, and his manner, so frank and earnest and kindly, was extremely winning." His reception throughout was that of a friend by friends; and he looked back upon his visit as a memory without a single stain of unpleasantness.

The noble nature of the man and his unselfish devotion to the science he loved is shown by his attitude towards financial reward. This lecture season brought him about $13,000 over his actual expenses, but he would not take a cent of it. He left it all in the hands of trustees as a fund for the benefit of science in America. At the present time this fund is in the form of three graduate fellowships in physics—at Harvard, Columbia, and the University of Pennsylvania. It is of interest to recall that one of our own men has recently enjoyed one of these fellowships.

Tyndall, like most of his friends, was a reverent agnostic. He did not believe that the ultimate truths of the universe could be expressed in words, or that our limited and finite intelligence could as yet comprehend them. His writings, however, contain many phrases which show that he was familiar with the books of Holy Scripture. And often, after a Sunday evening tea, he would join his friends in the singing of psalm tunes.

On the question of miracles, he did not deny their possibility, but he compares, for example, the horse power involved in stopping the sun and moon (or was it merely the rotation of the earth?) with the feeble efforts expended by Joshua and his men in pursuing the five kings of the Amorites. And with characteristic consideration for the author, he points out that for him the sun was only a moving lantern, whose motion could be varied at the will of the appropriate authority.

His views on the great question of the relation between science and religion were expressed in his presidential address before the British Association at Belfast. In this address he outlined the fortunes of science from the times of the Greeks and the Moors, and depicted the struggle of truth against ignorance and superstition. Tracing back the theory of Darwin to the beginnings of life, he saw only the unbroken workings of Nature, extending beyond the range of experimental evidence, and this led him to the conclusion that the possibility of life must have existed in the atoms of the nebulæ.

He strongly maintained the claims of science to discuss such questions fully and freely in all their bearings, whatever the results might be. Such an address, delivered at the present time, would cause scarcely a ripple of dissent, but at that time it brought down on his head the severe criticism of those who differed from him, and a three days fast was proclaimed to keep infidelity out of Ireland.

An accident in the Alps may have been the cause that turned his mind to investigations in another direction. Having taken a shower bath under the cascade of an Alpine stream, he was returning for his clothes when he slipped and the sharp granite pierced his shin. Dipping his handkerchief in the clear water of the stream he bound up the wound and limped to his hut, where he lay quietly for several days. There was no pain, and upon removing the bandage the wound was found to be clean and uninflamed. But it soon became inflamed, and he had to be carried on men's shoulders to Geneva, where for six weeks he was confined to his bed.

About this time there was considerable dissension regarding the spontaneous generation of life, and Tyndall could not let such a question of fact pass by without adding his own clear logic to the discussion.

In the investigations on radiant heat it had been necessary to use air from which all traces of floating dust had been removed. A sensitive test of such purity was found in a concentrated beam of intense light, which rendered visible particles smaller than any microscope could detect.

Convinced that the reported cases of spontaneous generation of life were due to infection from the air, he wanted to try the effect of this optically pure air. Fifty wooden chambers were built, with windows on each side for the passage of a strong beam of light. When this showed that the air within was free from floating particles, various infusions of meat and vegetable were introduced in open test tubes and properly sterilized. There was no shade of uncertainty in any of the results. All of the infusions remained pure and sweet, although some of them remained freely exposed to the air in the chamber for over a year. Out of a total of 500 chances, there was no appearance of spontaneous generation. But when the air from the laboratory was allowed to enter the chambers, the infusions swarmed with life in two or three days.

Believing in the germ theory, and realizing that in certain stages of development the germs are more readily destroyed by heat, he devised the method of sterilization by repeated heating. In this method the infusion is brought to the boiling point, and then set aside for ten or twelve hours, after which it is brought to the boiling point again. Successive heatings in this manner destroyed the most resistant germs, three minutes of repeated boiling being more effective than 300 minutes of continuous heating.

In recognition of these researches he was given the degree of M.D. by the medical faculty of Tübingen.

At the age of 55 he married the charming and accomplished daughter of Lord Hamilton, whom he met during one of his Alpine excursions. They were companions in all things, living in his rooms at the Royal Institution, and spending their summers among his old haunts in the Alps. But his later years were marred by ill health and sleeplessness, and by accident, one evening in 1893 he took an overdose of chloral, from the effects of which he never awoke.

No other man had done more by research, lectures and writings, to discover and disseminate a sound knowledge of natural phenomena. And because there was no sacrifice of truth for popularity, the books he wrote half a century ago are classics at the present time.

GOVERNMENTAL RESEARCH[1]

By GEORGE K. BURGESS, Sc.D.

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As an aftermath of war, the past two years have witnessed an unparalleled interest of world wide extent in the subject of scientific research, embracing its aims, scope and methods, as well as its relation to industry, university and government. A remarkable series of contributions and addresses, written mainly by leaders in, or directors of research, have called attention to the various aspects of the subject and have served to inform the public mind and stimulate it to a realization of the importance of research to the community on the one hand and the danger which attends ill considered plans on the other.

One of the most important forums for discussion of this fundamental subject has been the Royal Canadian Institute and I would like to recall, in this connection, particularly, the addresses before this Institute of Dr. George E. Hale on "Cooperation in Research" and Dr. Frank B. Jewett on "Industrial Research." It so happens that Messrs. Hale, Jewett and myself have been identified each with a separate and distinctive phase of the development of research; Dr. Hale with science unalloyed with industrial aspects or governmental control, Dr. Jewett with the applications of science to an industry, and the writer with scientific research in a government department. The preliminary training of each of us was remarkably similar; we are all graduates of the Masschusetts Institute of Technology, specializing in physical science and all had supplementary university training and some teaching experience, since which each has made his life's work in his chosen field of research of the three characteristic types, institutional, industrial, and governmental. We are all therefore exponents of the group method of carrying on research.

As a representative of this third type, that is, of research under government auspices, it may not be without interest to you to have from me a statement regarding the conduct of research in a Government Laboratory. I can of course do no better than give you the impression I have received from the development of the laboratories with which I am associated,

[1] Given at Royal Canadian Institute, April 24, 1920.

those of the Bureau of Standards, and especially in their relation to the public and the government in my own field of metallurgy.

I would first however call to your attention the tendency toward a somewhat different orientation of the relations of government to scientific research in the two countries that are most intimately related in blood and institutions to Canada, namely, Great Britain and the United States.

The relations of the British Government to research are set forth with great completeness in the annual reports of the Committee of the Privy Council for Scientific and Industrial Research and are ably summarized by Sir Frank Heath in an address before the society of Arts on "The Government and the Organization of Scientific Research."[2] The cardinal principles which have guided the development of this trust are set forth in Privy Council Committee's Report of 1918–19 and will bear repeating:

> We believe, in the first place, that while it is possible for the state by means of suitable grants to individuals or the generous support of universities and other independent institutions for research to encourage the pursuit of research in pure science, it is dangerous and even fatal to attempt to organize it. Research of this nature has no other aim than the creation of new knowledge and is impatient of the control which is inseparable from the idea of external organization. On the other hand, it is necessary for the modern State to organize research, including those simpler types of research which we may call investigation into problems which directly affect the well-being of large sections of its people. Such researches and investigation, deal either with applied science or if they are conducted in the realm of pure science are undertaken with a specific end in view. . . .
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> But in the second place, if the organization of research for public purposes is to be effective and economical which will be cognizant of the general lines of research undertaken by different departments of government, and a central body connected therewith capable of undertaking or organizing research which it is agreed can best be conducted by one agency in the interests of all.
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> In the third place, it is dangerous and even fatal under peace conditions for the state to attempt to conduct researches and investigations for the immediate benefit of industries which are not under state management. Industrial research is as integral a part of production or distribution as advertisement or insurance. But this does not preclude the state from encouraging the organization of research within an industry by means of grants-in-aid made under suitable conditions, or even by means of preliminary demonstrations of the valuable results which a well-conducted research may be expected to secure.
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> Finally, it would be fatal to the success of a department entrusted with the encouragement and organization of research to concern itself with exploitation or commercial development or administrative application of the results which may be obtained. . . .

[2] Sir Frank Heath, *Jl. Roy. Arts*, February 21, 1919.

It should be noted also that the English plan separates the administrative functions from the technical or scientific, the policies and progress of the latter being exclusively under the control of advisory committees composed of scientific or technical experts who are not members of the Department.

In the United State, the major branches of scientific research under governmental jurisdiction have not been gathered together under a single administrative head as in England but have been left each to the independent direction of the department of state in which it may be accidentally located, although there is now under consideration a measure that would group all the engineering and many of the scientific bureaus, except those dealing with agriculture, under a single Department of Public Works. The direction of scientific work, as at present organized, is almost exclusively in the hands of scientific men who combine the functions of an administrator and leader in research.

The American plan of independent administrative units does not mean that there are not often very intimate relations between scientific services in the various government departments including interchange of programs, partition of projects between them and other forms of cooperation maintained by a sufficiently close liaison, either formal or informal; although it could hardly be maintained that this common effort is as effective in all cases as could be wished. Again, certain scientific and technical services, such as the Advisory Committee for Aeronautics, are specifically constituted by law to include a membership from the several interested departments and the research work of this Committee is distributed among them. This method of bringing together the representatives of several branches of the service, some dealing with the application and others with the solutions of scientific problems in a definite field of research, makes for better understanding between theory and practice, and the scientific workers have the benefit of valuable advice from the men who are to use the results of the investigation. This constant interplay is beneficial to both. This method of joint research control could be extended with advantage to many other fields of the applications of science in which the government is interested.

One of the most important and fundamental fields of general interest, in which a beginning has been made to bring the departments together, is that of standardization and specifications. It has been proposed to make the Bureau of Standards a clearing house of information—to use the British term—on these subjects for the government. There are great possibilties here

for realizing economies in purchases and improvements in design and there will also result inevitably a considerable impetus to scientific research, especially on fundamental constants and properties of materials which form the basis of constructing standards and writing specifications. The formation of the American Engineering Standards Committee, in which the Departments of Commerce, Navy and War are represented and which is now working in a highly satisfactory manner, forms a further liaison with the public through the Engineering Societies, which again makes for development and improvement in many domains tributary to scientific research.

In looking over the multiplicity of research projects supported by the United States Government, one might easily get the impression that with such a widely scattered responsibility, as actually exists, for the planning of research in the various government departments, there might arise considerable confusion and duplication. A careful survey of the situation, however, would soon convince one of the surprisingly slight amount of overlapping in the scientific work among the several departments. I can speak with some positiveness on this subject as I have been recently occupied in such a survey as a member of the Board which has just completed a study in duplication in scientific work carried on by the government; and it is a fact that actual duplication is almost non-existent.

Although there are in the United States for certain lines of governmental scientific research, such formal or informal advisory technical committees as mentioned above, the rôle of initiation, correlation and stimulation of research, including industrial scientific research, taken in England by the Department of Scientific and Industrial Research, has been, in the United States, largely assumed within the past year or two by the National Research Council, the organization and scope of which has been so ably set forth before this Institute by its first Chairman, Dr. Hale.

The impetus given in England by the Government to the organization and support of Research Associations has been, it seems to me, one of the most remarkable of recent achievements in the successful intervention by a government for the encouragement of national industries by aiding in the formation of a type of organization by which the industries can best help themselves. The crucial test of this method of stimulating industrial research will in all probability come after the five years time limit of government support is reached when the Research Associations will have to shift for themselves.

The Research Council has been endeavoring to foster in the

United States the formation of somewhat similar cooperative scientific research associations among several of the American industries, but to this date, it would appear safe to say, with but indifferent success. It is perhaps, not too early to ask, why does the formation of such Research Associations readily succeed in Great Britain and apparently not in the United States? Is it because of government initiative and support that they are established so promptly in England and would they be eventually in the United States if such support were forthcoming? Is it, that in the United States the industries are already provided with all the research assistance they need or can make use of? Or, on the other hand, can it be argued our industrial leaders are not yet convinced of the value of this type of cooperative research? I do not venture to answer these questions, replies to which in the last analysis may be but a formulation of underlying national characteristics; but possibly you in Canada by your solution of the problem will help shed light that will aid us all.

What has been the policy of the Government of the United States toward scientific research and its applications to the industries of the country? To put the question is to call forth immediately, what is familiar to you all, the response that in many fields, notably in the agricultural sciences, the Government has been the most generous of sponsors. It is also supporting research in almost all domains of pure and applied science from astronomy and mathematics to metallurgy and road construction, and in many other branches than agricultural research it has been the pioneer and still is the leader. Moreover, in recent years, there has been a marked advance in governmental support of scientific research fundamental to industry, particularly as exemplified by the Bureau of Mines and of Standards.

So much has been written recently about the advantages, including atmosphere, surroundings and status of research conducted under university or institutional guidance on the one hand and in industrial establishments on the other hand, and so little has been said—and silence may appear to be more eloquent than speech under certain conditions—of the advantages of research under governmental auspices, that it is difficult to resist setting forth here some of the conditions, as I see them, of research in a government department and of the position of the scientific men in the government service.

If government service, which we must remember is service for the public, is so unattractive, as certain writers have intimated, why for instance has the senior scientific staff of the Bureau of Standards remained nearly intact from its founda-

tion nearly twenty years ago? There must be some other than pecuniary advantages to account for this stability of position among scientific leaders, which has been the rule, rather than the exception, until very recently in most of the scientific establishments of the American government. The present moment, marked by scientific men leaving the government in unprecedented numbers, may be accounted for primarily by the bidding for their services by industries and institutions that have been able to readjust their salary scales to meet the mounting cost of living more promptly than had the government. It is within reason to suppose however that this situation will be eventually readjusted.

What then are some of the advantages to the scientific man of his position in the government service as compared with the university man or the man in a research laboratory pertaining to industry, The attributes the research worker most cherishes are freedom for development within his chosen field; unhampered opportunity to publish the results of his discoveries; the stimulation afforded by the congenial atmosphere of sympathetic and critical co-workers; an absence of extraneous, irksome tasks; in the existence and maintenance of the ever changing material facilities for research. Taking the Bureau of Standards as a type of governmental institution devoted largely to scientific research, I can state from experience I know of no other type where these desirable attributes are more happily blended than here.

There is also the added satisfaction, or privilege if you will, the "government scientist" possesses, in that he is conscious of working directly for the public welfare in response to a public demand, expressed through the representatives of the people in Congress by their allotment of funds to support his work. This direct relation to the public—and it is much more intimate than many persons realize—gives him a pride and confidence in his accomplishments that cannot be had by any one working solely for himself and his science or for an industry or commercial firm. His sense of responsibility is enhanced and he will plan his work accordingly. As he demonstrates his ability to make efficient use of it, his freedom of choice of subjects is almost unlimited, and he has absolute liberty as to his methods of attacking the problems he sets out to solve. I wonder if more can be said for any other type of research center?

The craving to communicate his ideas and exhibit his work to others is a well-known trait of the scientific man. Among the hundreds, nay thousands of investigators in the industrial research laboratories the ideals of which have been outlined by

Messrs. Jewett, Mees,[8] Carty, Nutting, how many of these men have the opportunity of free communion with others? On all important problems—important from the technical, competitive point of view—absolute silence is usually the most rigid of pass words. What might become many able contributions to science never see the light of day, on account of, what appears to me, a misguided policy of secrecy which often extends to unessentials, from the manufacturer's point of view, in an industrial research laboratory. The following is an illustration among many: the director of a long-established industrial research laboratory showed me the other day the reports on a series of long since completed but as yet unpublished investigation of considerable general interest, two of which had just been duplicated and published by the Bureau of Standards where we had no knowledge of the previous work. In addition to the economic waste of unnecessary duplication, what is the effect on the morale of the men who did the work first and had it suppressed except for use in the plant?

The benefits of association and working in a community of considerable size where there may be rapid interchange and immediate availability of information and experimental facilities are often overlooked by those who advocate the advantages of research by lone individuals in the conditions of practical isolation often prevailing in even our larger universities. The laboratories of the government, and to a less extent the larger industrial laboratories, should be and unquestionably are able to secure more rapid progress and greater effectiveness in the execution of research than can the isolated worker.

Then as to the facilities or tools of research, the public laboratories, speaking generally, are better equipped than most private laboratories, although some of the industries maintain laboratories before which even the government laboratories pale. The industrial research laboratories to be effective must also possess as adjuncts development laboratories for manufacturing on an experimental scale. In pure science there are many problems, often the most fundamental such as the exact determination of physical constants and standards, which require very elaborate and costly layouts and often take a series of years for their completion. Such can best be left to the government laboratories.

It would thus appear that viewed from these various standpoints of freedom, publication, facilities, atmosphere, so dear to

[8] C. L. K. Mees, "The Organization of Industrial Scientific Research," McGraw Hill, 1920, contains an excellent bibliography of recent titles.

the research worker he is at least as well off in the government laboratory as elsewhere.

As an example of the operation of a government research laboratory in the United States, let us take the Division of Metallurgy of the Bureau of Standards. What does it do and how?

First as to organization; the Bureau is divided for administrative convenience into twelve divisions, the office, the plant, the shops, and nine scientific or technical divisions, each constituting one of the branches of scientific work carried out at the Bureau, electricity, optics, heat, chemistry, weights and measures, metallurgy, engineering physics, structural materials, ceramics. Each division is again divided into sections; thus in metallurgy there are sections of: (1) Microscopy and Structure of Metals, (2) Heat Treatment and Thermal Analysis, (3) Working and Miscellaneous Properties, (4) Chemical Metallurgy, (5) Foundry.

The methods of directing and conducting the research work within the division we may mention briefly. There are no rules and regulations. Funds are allotted to the Division either by direct appropriation of Congress for a specific purpose or from the general funds of the Bureau by the director. Each research is authorized by the director on the written advice of the division chief. At meetings of the leaders within the division the program of work is considered and as a result of these discussions supplemented by written estimates the divisional budget is made up. Frequent conferences of the leaders are held to determine questions of policy and the progress of the work is fully discussed. Occasional meetings of the separate sections are also held, and there are also constantly being held informal conferences of members of the staff interested in any problem. The whole Division meets once in two weeks when a formal presentation of some investigation is given by its author. Each member of the Division presents a monthly progress report in writing. The papers offered for publication are reviewed critically by a committee of experts within the Bureau. A personnel committee consisting of all chiefs of divisions passes on most promotions.

The supervision of the routine work of testing and standardization is carried out by the leaders in research covering the same subject. There may or may not be a distinction between the personnel engaged in testing and research depending upon circumstances. This arrangement makes for flexibility, and avoids indivious distinctions and has worked extremely well. Men showing an aptitude for research have the oppor-

tunity to show it even if they may be assigned originally to routine work, and conversely. The skeleton of the organization is however of little importance as compared with its spirit. The Bureau of Standards consists above all of men and women imbued with high ideals and is a living organism of the highest type.

The Division of Metallurgy was formed in July, 1913, and has grown in population from one to fifty-seven and has acquired a very complete equipment to meet the needs of metallurgical research and testing. Over the development of testing we have no immediate control. The public and the government departments send us what they will and we try to satisfy their demands. It is a remarkable fact worthy of note that whenever a new line of testing is announced, immediately there is set up a never-ceasing flow of materials or instruments for test, the volume of which is oftentimes embarrassing; and in consequence one of our most difficult problems is to adjust equitably our efforts as between the execution of tests, our routine work, and the carrying out of investigations, our preferred work of at least equal urgency. There is here of course the ever present danger of too easily choosing the immediate for the permanent. Although not so vociferously expressed the real demand for knowledge concerning fundamental constants and properties is at least as great as the need expressed in the polite but insistent requests for the report on a trivial test of a material of interest to but one party. We are obliged to remind ourselves at times that we are here to serve the best interests of the public in our several domains of science.

The field covered by our metallurgical researches and investigations embraces subjects confined mainly to what has been called products metallurgy as distinguished from what is called process metallurgy which latter is illustrated by the reduction of metals from their ores, the field of the Bureau of Mines.

As one of the subjects of metallurgical research which will undoubtedly have far-reaching consequences, mention may be made of the study of gases in steel, including the development of methods of analysis; the determination of the quantity and manner on inclusion of the several gases which may be present such as oxygen, nitrogen, hydrogen and the oxides of carbon; and the characteristic gas content for steels of different composition and as determined by the method of manufacture. An immediate application of the methods here employed has been developed in our investigation of steel welding methods and products. The clearing up of the behavior of welded metals as

influenced by its gas content will aid greatly in solving some of the difficult problems connected with the welding art.

We were greatly concerned during the war with the scarcity, real or threatened, of several minerals and metals of vital necessity to the industries of the country. Among these were manganese, tin and platinum, and it became necessary to modify manufacturing process and devise suitable substitutes. We did a great deal of research work along these lines. Thus in the case of tin, for example, which is all imported, we developed a satisfactory solder containing only ten per cent. of tin instead of the usual 40 or 50 per cent. This solder containing also 80 per cent. lead and 10 per cent. cadnium was as cheap as ordinary solder. The tin content of bearing metals for most uses, it was shown, could be very greatly reduced; and for the tin bronzes satisfactory alloys, if made of available metals, were substituted. In fact, I believe America could have carried on with some ten per cent. of the normal tin consumption.

A great deal of attention is given constantly to questions connected with the various types of failure of metals and metal products such as flaky steel and internal fissures, railroad materials and stress corrosion in structural bronzes, to mention but two types, and numerous papers on these subjects have been published by the staff. The various and puzzling aspects of the corrosion of metals also requires constant attention.

There is now under way a series of investigations on special steels including structural steels, high speed steels, and their substitutes, high chromium steels of various types, and of steels containing unusual elements.

Some of the other subjects of metallurgical research are copper crushes guages for testing powder, improvement of machine gun barrels to resist erosion, identification tags for the Army and Navy, spark plug electrodes, characteristics of bearing metals, metals for aeronautical instruments, centrifugal steel castings, comparison of ingot practice in steel manufacture, temperature control of metallurgical manufacturing operations, embrittling of the steel parts by cleaning, pickling and plating, standard test bars for various alloys, and many other matters.

I shall not tire you, however, with an enumeration, much less with a description, of each of the seventy odd research problems in metallurgy with which we are occupied. They may be found in summary form from year to year in the annual reports of the director and appear in detail as they are completed in the publications of the Bureau and the scientific press. I may mention, however, some of the broad lines along which we

are orienting our work and in doing so will endeavor to emphasize the cooperative aspects of this research work, for much of it is undertaken after consultation or in active participation with other groups having also an interest or a part in its accomplishment.

This cooperation in research takes several forms and is of various types; thus there may be one or more of the other departments of the government interested in the prosecution of a research in which we also have an interest. For example, there has been carried out an investigation of considerable magnitude on the development and properties of a series of special steels with a view to their serviceability for light armor; in that research the Bureaus of Mines, Standards and Navy Ordnance have participated. Again, in consultation with the Advisory Committee for Aeronautics a series of researches on light aluminum alloys have been carried out. For the Army Ordnance, and sometimes in cooperation with that establishment, a whole series of investigations have been executed or are still under way. The list of interdepartmental cooperative researches in metallurgy is of quite considerable length, but the above illustrations may suffice to show that to secure scientific coordination among the government departments a central body is not indispensable.

Turning now to our cooperative relations with non-governmental bodies our relations with some of the scientific and technical societies are very close. Thus the work of the American Society for Testing Materials is largely participated in by the Bureau and particularly in Metallurgy our work has often been oriented to meet the desires of the various technical committees which are planning important lines of research of interest to science and industry; for example, coated metals, corrosion of iron and steel, the standardization of ladle test ingots in steel making.

With the National Research Council and its several committees on metallurgical matters we are in most active cooperation; I need but mention the work of the Pyrometer Committee and the extraordinarily successful symposium on pyrometry held at the meeting last fall of the American Institute of Mining and Metallurgical Engineers.

There is still another type of cooperation that should be mentioned, namely, the solving in the government laboratory of some of the problems fundamental to manufacturing processes and standards which are of interest to an industry as a whole. The development of this type of cooperative industrial research is still in its infancy in the United States, and evidently requires

an experimental manufacturing plant for each type of industry. We have made some provision for this field of development in metallurgy by installing several operating or semi-manufacturing units which, on a quarter ton basis, will allow us to make any metal or alloy, submit it to various heat treatments, shape and work it by rolling, forging, or drawing.

I should like, before closing, to call your attention to a cooperative research of the greatest economic importance, conceived on a somewhat more comprehensive scale than anything else we have hitherto undertaken; I refer to the investigation just gotten under way under the auspices of a Joint Committee to study the effects of sulphur and phosphorous in steel and in the specifications for the various grades of steel. This is a subject about which there is a great deal of diverse opinion and the experimental results published thus far have not been considered of sufficient weight to justify changing the present and long accepted values of sulphur and phosphorous contents in steel by responsible specification making bodies.

The Joint Committee, the chairmanship of which is held by the Bureau of Standards, is constituted with representatives of the government including the Departments of Commerce, War and Navy, steel makers, and specification making bodies including the American Society for Testing Materials, the railroads, the automotive and shipping industries. It is hoped, in view of the fact that the program of tests is mapped out by unanimous agreement of all interested parties; the steel manufacture witnessed by representatives of all interests; and the tests carried out in government laboratories, that the results of this elaborate research will be determinative as to revision of the specifications in question.

With this summary review of a few of the aspects of governmental research, as I see them, and as illustrated specifically in the work in Metallurgy at the Bureau of Standards, I trust you will carry away the impression, which I have endeavored to convey, that there is a human side to research and that in the government service it is possible to be very close to the public, in fact a part of the public and not a group set apart to solve abstruse problems of little general interest. I believe it not only desirable but absolutely essential that a government laboratory, and by that term I mean the men who work in it, keep in closest possible touch with the professional as well as the nontechnical public it serves and that a crucial test of the usefulness of such a laboratory is the interest and above all the confidence it inspires.

THE MATHEMATICIAN, THE FARMER AND THE WEATHER

By THOMAS ARTHUR BLAIR

METEOROLOGIST, U. S. WEATHER BUREAU

IT may have been true when Mark Twain said it, "Everybody talks about the weather, but nobody does anything," but now-a-days the mathematicians are doing something. They are hitching the weather to the engine of a formula, measuring it with the yardstick of an equation, and weighing it in the balances of a co-efficient. They can tell how many million dollars a half inch of rain on the fifth of August will add to the corn crop of Ohio; how many additional automobiles the farmers can purchase as a result of a week of warm weather while the wheat heads are filling; and how much smaller the world's supply of cotton will be because of an August drought in Georgia.

Aspiring poets used to lament that all the possible figures of speech were long since exhausted, but the poets of to-day still find something new to say and new ways to say it. So the prosaic, practical scientists are saying something very new about three of the oldest subjects of human thought, weather, farming and mathematics. The weather is the oldest of them all as a basis of observation and remark; the practise of agriculture began early in the history of civilization, and the development of mathematics began soon after, notably among the Egyptians, and was carried to a high degree of excellence in some lines by the Greeks. Yet each of these is the subject of an extremely new and modern science. Meteorology, the science of the weather, is one of the newest of the sciences, and is yet in its infancy. Its beginnings date back to some observations made by Benjamin Franklin, but its application began a century later, just after the Civil War. Something of the growth of the modern science of agriculture, principally due to the work of the agricultural experiment stations, is known to all. In the old science of mathematics new theorems, processes and devices are constantly being developed. But now appears a group of men with an original idea. Knowing something of the modern aspects of each of these sciences, they are combining them and using the refined and elegant processes of mathematical statistics to determine the effect of various kinds of weather upon the

crops in their different stages of development, to ascertain the farmer's risk from unfavorable weather, and to find definite relations between weather happenings in different parts of the globe.

The mathematical processes are due largely to Professor Karl Pearson, of England, who has applied them primarily in the fields of biology and anthropology. In this country, the leader in the application of these methods to the problem of determining the influence of the weather on the crops is Professor J. Warren Smith, of the United States Weather Bureau, whose work in this line began in Ohio several years ago. For example, he has shown that the yield of corn in Ohio is very largely dependent upon the amount of rain in June, July and August. When the July rainfall is less than three inches, the average yield is 30 bushels per acre, when it is five inches or more, the yield is 38 bushels; which means that these two inches of rain have added 27,300,000 bushels to the corn crop of this State, worth at 1919 prices about $35,000,000. When the July rainfall is three and a quarter inches, the yield is 15,000,000 bushels greater than when it falls short of this amount by half an inch. Each quarter of an inch increase between the totals of two and four inches means an added value of about $7,800,000. Taking the four great corn-growing states of Indiana, Illinois, Iowa and Missouri, the addition of half an inch to a total of two and three quarters inches adds ten bushels per acre to the yield on the average. This thin layer of water is worth at present prices about $13 an acre, or a total for these four states of the Corn Belt of the significant sum of $4,000,000,000. Truly, if corn is king in this region, water is the power behind the throne.

But not content with this victory, the agricultural meteorologist advances to the next line of defense with the relentless weapons of statistical analysis, the machine guns of mathematics, and finds that the most important twenty-day period in Ohio is from July 21 to August 10; and finally goes over the top and locates the critical period in the first ten days of August. This is the time when the half inch or the quarter inch of rain is of the most value, and when you must have it if you are to get a big crop of corn. And this is the period immediately following the blossoming of the corn. Now, this idea of "critical periods" is new, the idea being that there are certain short periods of time in the growth of any crop during which its future prospects are largely determined, "a tide which, taken at the flood, leads on to fortune." In short, favorable weather at these times will produce a good crop and unfavorable weather

a poor one. In some crops this is a single short period; in some temperature is the most important, in others it is rainfall or sunshine.

Food is brought to the plant by the moisture in the soil and is converted into vegetable tissue by heat and by the direct action of the sun's rays. For every species of plant there are certain best temperature and moisture values, varying at different periods of growth. If these best values occur at the critical periods, excellent crops are certain, barring accidents. And here we arrive at a practical application; the climate of most places in the United States is pretty well known and completely exhibited in published tables. When tables of the critical periods of plant growth, together with the meteorological factors, whether temperature, rainfall or sunshine, most affecting growth at these times, likewise become available, we shall have but to compare the two sets of tables to determine whether a specific crop is climatically well adapted to a particular district. Further, there are ways of advancing or retarding, within certain limits, the time of occurrence of the critical periods, thus bringing them into the time when favorable weather is more likely to occur. This may be done by the use of an earlier or later variety, by varying the time of seeding, by cultivation, or by the use of fertilizers. Moreover, by cultivation, a quarter or even a half inch of moisture may be conserved, if the farmer knows just when it is most important to conserve it. If these methods fail, and the weather is still frequently unfavorable at critical periods, it will be necessary to substitute some other crop. In some cases these important periods are far enough ahead of harvest to enable increased attention to be given to other crops in the same year. For instance, the rainfall of May is the most important factor in the hay crop in most of the northern United States. If at the end of May the rainfall has been light, other forage crops may be planted to take the place of hay. The application of all this to farming under irrigation is obvious. In our arid and semi-arid west, the sun may be depended upon to supply an abundance of energy, and if just the right amount of water is applied at the right time, remarkable crops result. Hence the importance of knowing the right time.

I have referred principally to Professor Smith's study of the effect of the weather on the yield of corn in Ohio, but many other interesting results have been obtained, both by him and others, and both in this country and in Europe. Take wheat for example, one of the oldest and probably the most important of cultivated crops. In the growing of winter wheat, which is

exposed to all sorts of weather for nine months, through fall, winter, spring and summer, the weather of three or four ten-day periods in May and June is found to influence the crop to a much greater extent than that of all the rest of the time combined. These are the critical periods in the development of winter wheat, and they are associated with certain definite stages in the growth of the wheat plant. When the wheat is "jointing," that is, growing rapidly in height, cool weather is demanded, but later, while the heads are filling, it must be warm, and in between these periods, during the ten-days when the "boot" from which the head emerges is forming, dry weather is necessary for the best growth. There is indication also that cool weather is advantageous while the wheat is blossoming, and warm while it is ripening. In addition, a weight of evidence is accumulating that a heavy March snowfall is decidedly detrimental, contrary to the prevailing popular opinion.

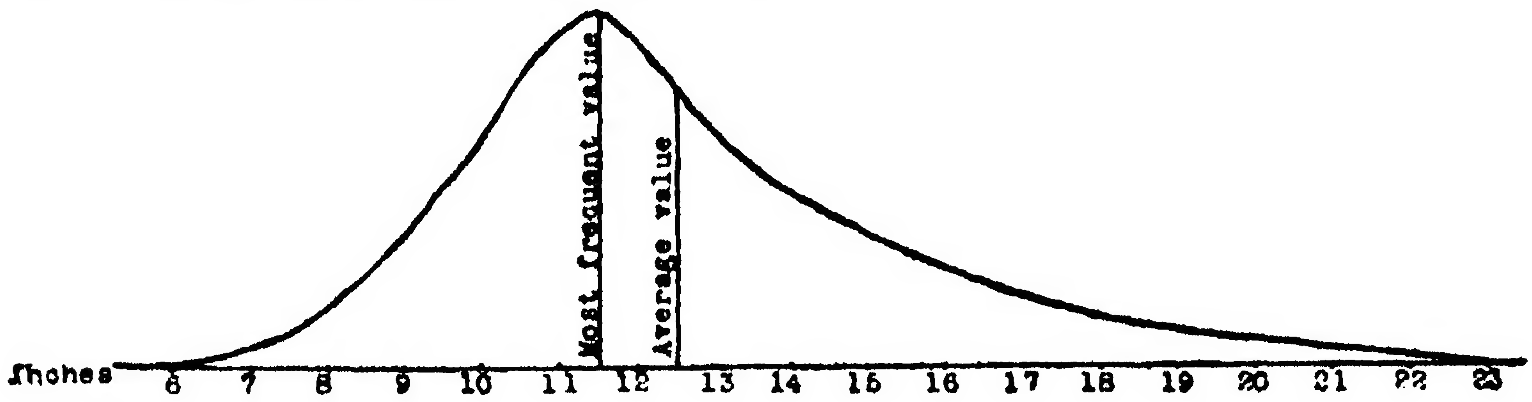
In the great spring wheat centers of North and South Dakota, it has been shown that the yield depends largely on the rainfall of May and June and the temperature of June, but no shorter critical periods have as yet been established. To obtain a large crop, the rainfall of May and June should be above the average and June should be cooler than the average. In North Dakota, which is the drier and cooler of the two states, a good rainfall is more important than cool weather, but in South Dakota temperature is in a great measure the determining factor, while in the neighboring State of Minnesota, variations in either temperature or precipitation during these months have little effect on the yield. No general rules for the entire country can be made, but each section must be studied with reference to its normal climate.

Consider, as another example, that staple of our dinner tables, the potato. A cool and wet July makes the potato crop in the Mississippi Valley. Cool weather is desirable all summer and wet weather during June, July and August, but July is the most important month and the first ten days of July the most important short period. This is the ten days following blossoming. If it is cool during this time with a good supply of moisture, and in addition the moisture supply has been fairly good during the previous two or three weeks, the prospects for a large crop of potatoes are excellent. If these conditions have not obtained, the yield will be small. If the water supply can be controlled by irrrigation, it is of the greatest importance that it be sufficient at this period.

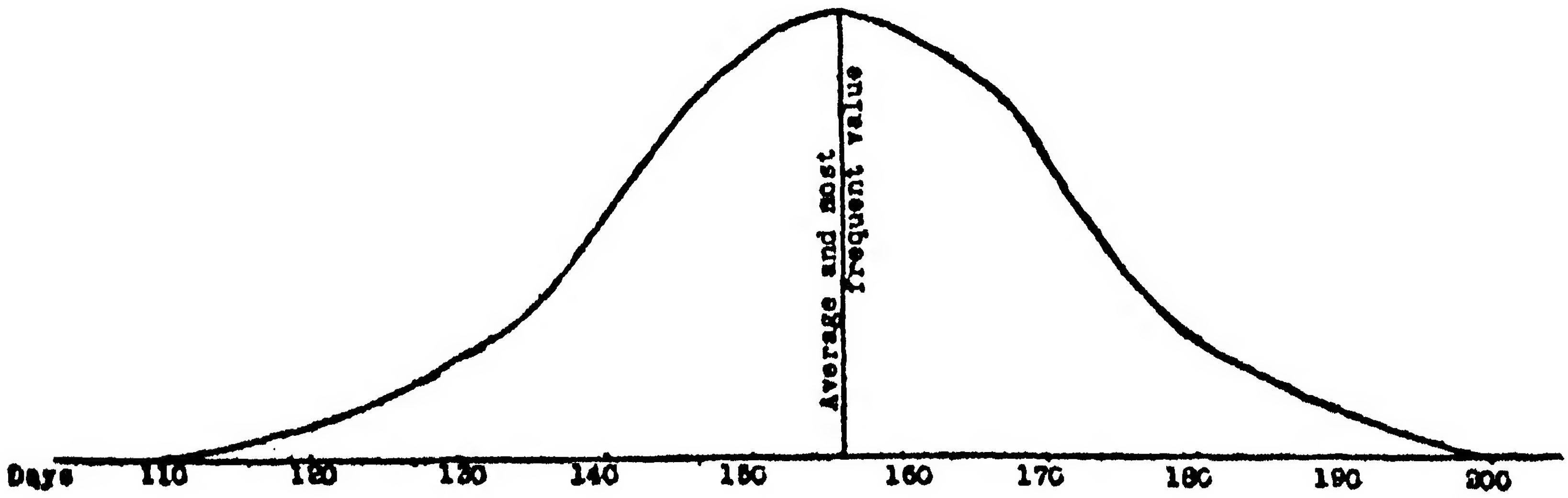
In the great Cotton Exchange in New York and in the primary cotton markets of the South the price of cotton has always fluctuated from day to day during the growing season with the daily reports of weather conditions in the Cotton Belt, where the world's supply of this staple is largely produced. But it has fluctuated erratically and without any solid knowledge of the exact amount of influence the weather may have upon the yield. Recently, however, a well-known American economist and statistician has shown that he can predict the total yield with remarkable accuracy by mathematical analysis from a knowledge of the average weather conditions from May to August, an accuracy greater than that of the estimates based on the condition figures of the Government crop reports. The favorable weather conditions differ somewhat in the different sections of the Cotton Belt, extending from Texas to South Carolina, but the most important requirements are that May shall be dry, June both warm and dry, and August cool and wet, a cool and wet August being of most importance. Sitting in his New York office, without even having seen a cotton plant growing and without receiving any reports as to the progress of the crop, the master of the newer statistics can at the end of August insert these weather values in his formula and tell how much cotton will be ginned in the South during the following autumn and winter. Such, in the hands of experts, is the magic in those bugbears of our school days, arithmetic and algebra!

There is another phase of weather, not directly connected with crop yields, towards which the powerful weapons of the mathematician have been directed. This may be called the application of frequency curves to climatic phenomena. A frequency curve offers a systematic method of examining the variations in a series of events, and, as applied to weather and climate, may be used to determine how often the summers will be too hot or too dry for a particular crop, or the winters too cold, or the growing season too short. The simple average, as usually given in climatic tables, is not sufficient. We must know how the individual years arrange themselves around the average. For, though these climatic events occur according to the laws of chance, they do not all follow the simple law by which, if you flip a coin a large number of times, heads and tails will appear with equal frequency. On the contrary, some of these happenings form "skew" curves; the rainfall, for example. In parts of the semiarid west an annual precipitation of twelve inches is considered sufficient for the growing of dry land grains, but that average will probably be made up of a few

years with much more than twelve inches and many years with amounts somewhat less than twelve. Though twelve is the average, it is not the most probable amount, and falls of less than twelve are more likely to occur than those of more than twelve. In such cases the distribution of events about the average is unsymmetrical, askew, and the average does not mean much, does not tell us what we want to know.



SKEW FREQUENCY CURVE SHOWING DISTRIBUTION OF ANNUAL PRECIPITATION AT CORINNE, UTAH. Average value, 12.5 inches; most frequent value, 11.5 inches.



SYMMETRICAL FREQUENCY CURVE SHOWING VARIATION IN LENGTH OF GROWING SEASON AT DENVER, COLORADO. Average and most frequent values coincide in 156 days.

The farmer or buyer wants to know not only what the average amount is, but how often in the course of ten or fifty years the amount will fall so far short of the average as to be entirely inadequate. This the makers of the frequency curve can tell him much more accurately than he could do for himself by simply counting the number of times it has been insufficient in the past ten or fifty years. In the northern portion of the orange-growing section of Florida, once in a good many years the trees are killed or badly frozen back by a winter cold wave. To know how often this is liable to occur is of prime importance in fixing the value of the land for orange-growing purposes. Similarly, in peach-growing sections, farther north, peach trees or the buds for next year's crop are subject to winter killing, and in nearly all fruit-growing sections the crops are liable to injury by late spring frosts. In early vegetable farming, the farmer frequently wants to take the risk of having his crops killed once in five or ten years in order to be in the market early in the other years. Is it better for him to go it

blindly, depending on his own impression of the proper date of planting, or to rely on the theoretical determination of the risk, which in 73 per cent. of the cases will lead to no unexpected losses, and in 94 per cent. to not more than one such loss in a period of twenty to thirty years?

In such cases as these the object is to determine the average interval between the occurrence of certain unfavorable conditions, such as insufficient rain, late spring frosts, early autumn frosts and other adverse events. This is the question that is answered by these curves, for by a little additional calculation the "frequency" curve becomes an "average interval" curve. By the use of these devices of the mathematician, it becomes possible from the examination of a limited number of observations to obtain a reasonable estimate of events as they will occur in an unlimited series of observations and hence to predict what is going to happen on the average in the next 20 or 100 or 1,000 years. Of course, it is not possible to tell by these means, nor by any others now known, just when such unfavorable events will happen. They may occur in two successive years and not again for 20 years. But, though they appear to happen fortuitously, in the long run they will occur the number of times indicated by the curve, and it is the performance of the land and the weather in the long run that determines values, though to the individual farmer the events of a few specific years may be of first importance.

The application of the statistical method to this individual phase of the problem, in what has been called "weather insurance," offers a legitimate opportunity for an extension of the field covered by insurance companies. We now have marine insurance, which includes perils of the sea due to storms, also hail and tornado insurance in certain parts of the country, but the idea may be greatly extended. Basing the work upon the methods I have described and upon the accurate climatological data collected by the Weather Bureau, there should be a statistical determination of the farmers' many risks from unfavorable weather conditions. Then the proper charge against the weather hazard can be made, and unseasonable and unusual weather will cease to be a calamity to the individual, just as the financial losses by fire and death are minimized in fire and life insurance, and the burden which is at present carried by individual losses and by depreciation of land values will be more widely distributed.

With such insurance well established it will be applicable in a wider field than the distribution of the individual risk. The

insurance rate quoted on a farm will give the purchaser valuable information. The country banker and storekeeper, who frequently carry the farmer through bad years, will be able to insure themselves against a great drain upon their resources in any one year. Instead of the haphazard, unbusinesslike method of taking unknown chances, which characterizes much of the present practice, the weather becomes a determinate risk in farming, a risk that can be stated more easily and more accurately than most other business risks.

Turning now from the numerous climatic problems of the agriculturist to those even more extensive fields of investigation, the physics of the atmosphere as a whole and the interrelations of its various parts, we find that the mathematical weather men have brought to light another series of interesting and curious facts. When an English scientist announces that it will be warm in Cairo, Egypt, to-morrow, since it was cold in London to-day, and that the rainfall will be unusually heavy in England this winter, since it was unusually light in Cuba last summer; when another says that a light rainfall in Chile during the period from May to August will be followed during July to October by more than ordinary floods on the Nile; when a Japanese mathematician says that the rice crop in northern Japan will be large this fall, since the barometer was unusually high last spring over China; when the scientists begin making such long range and curiously disconnected forecasts as these, it would seem that they are beginning to understand something of how this complicated atmosphere of ours works. As a matter of fact, they are conservative, and do not make any such forecasts for individual periods, but they have shown that on the average and to a great extent such relations do hold.

Many such correspondences between weather happenings in widely separated parts of the world have been shown. The rainfall of the central United States shows a direct correspondence to that of central South America, and both show an inverse relation to the rainfall of Australia. A forecast of the temperature at Berlin in March and April is possible at the end of December from the temperature at Christiania, Norway. When the April temperature at Irkutsk, Siberia, is higher than the normal, we may expect with a high degree of probability that the temperature at San Francisco in the following July will be abnormally low, and conversely. The higher the barometric pressure in the Argentine and Chile during March and April the greater will be the monsoon rainfall of India the following July and August. Florida and southern California refuse to pull

together in the matter of weather. Especially in the winter months, when one is warmer than normal, the other insists upon being cooler. Starting with San Diego as a basis of comparison and moving east and north, we find that the temperatures show a decreasing correspondence to those at San Diego, until, in the Mississippi Valley, the relation changes from positive to negative, and the eastern part of the country generally has temperature conditions opposite to those in southern California, culminating at Jacksonville, Florida, in a high degree of contrariness. Thus, it is fortunate for the orange market that freezes are not likely to occur in Florida and California in the same winter.

Such are some of the curious but apparently unimportant facts which have been revealed by the application of these novel methods of investigation to the study of climatic data. They are evidence that our entire atmosphere functions more or less as a unit, and though some of the results may seem at first sight to be of little moment, they promise in the end to prove of the greatest value. Their significance lies in the fact that they are leading toward an understanding of those great motions and shiftings of the atmosphere which cause our changeful weather, and make one winter to differ from another winter in severity as one summer differeth from another summer in torridity. A thorough understanding of these movements should, in time, lead to the solution of that fascinating problem of the climatic forecast, now the realm of charlatans, but the dream of real scientists, which aims at predicting the general character of a season months in advance. When that time comes, the mysteries of the weather largely will have vanished, and the meteorologist may say with the Wise Man in Yeats's play, "I have made formations of battle with Arithmetic that have put the hosts of heaven to the rout."

ANCIENT BACTERIA AND THE BEGINNINGS OF DISEASE

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GERMS are among the oldest inhabitants of the earth. It is even suggested that while the earth was still forming bacteria were carried from distant planets on meteorites and thus initiated life on the earth. However this may be, bacteria are found in the oldest fossil-bearing rocks of North America, having been discovered by Dr. Charles Walcott in the central portion of Montana in association with fossil algæ, in the substance of which the bacteria were fossilized. Far from being disease-producing these earliest types of bacteria were doubtless of the kind which assist in withdrawing calcium from the sea water. They were rock builders. An analogous form exists in the Atlantic Ocean at the present day, and is especially active around the West Indies in building up the coral reefs.

The form of these most ancient germs is so similar to that of recent bacteria that they are called *Micrococcus*, a bacterial form which is especially common to-day. Considerable comment has been aroused as to the possibility of such delicate organisms as bacteria being capable of preservation in a fossilized condition. This is, however, pretty definitely settled by investigations in other lines. Fossil brains, fossil flowers, fossil blood and fossil muscle are known to be so well preserved that there is permitted an examination of the minute structure of the tissues. Renault, too, has described a great number of bacteria in the coal of France so no doubt exists longer as to the structures seen being bacteria.

Disease, however, did not exist with the most ancient bacteria. They were harmless, as are most of the present-day bacteria. Whether bacterial organisms were instrumental in effecting the origin of disease we do not know. This is a wide field of study which has not yet been explored. In a later geological period bacteria are found in partially decayed bone, together with thread mould and other types of fungi. This condition, however, can not be regarded as disease, but decay in dead material. The earliest animals were free from disease, although they were subject to injuries incident to the life of any

creature. The larger attacked the smaller then as now. Infection of the injured part did not take place in the early periods of animal life, and it is only after the great Coal Period that infected wounds are found.

The Coal Period witnessed the earliest widespread condition of bacteria and fungi, and possibly witnessed the beginning of disease, although there had been previously a mild form of pathology due to the action of parasites. The first diseased conditions preserved are, of course, not the earliest manifestation of disease, since disease is doubtless the result of long ages of struggle between the two contending forces of nature. The early animals were so highly immune to attack by bacterial organisms that it was only after the races of animals began to grow weaker through age that disease was able to make any headway.

It is idle to attempt to place a beginning of any limited time during which disease began. Disease was not present in the earliest times of the earth's history and it did not become very active until the present age of the earth had been attained by nearly three quarters of its duration. That is, disease has only been active during the last one quarter of the earth's history, so far as animals and plants are concerned. The incidence of maladies began slowly, was introduced gradually, and has been an important factor only within relatively recent times. It was a minor and unimportant factor for millions of years.

The action of early parasites on the shells of ancient animals are our oldest evidences of disease. The action of these organisms resulted in the formation of the oldest tumors. Diseased conditions of a very interesting type were caused in the early history of animal life by poisoning of the waters in which the animals lived. This resulted in a thickening of the shell, a twisting of the spirals of snails, or a diminution in size of some forms, certain of the depauperized individuals being only one twentieth their normal size.

The origin and development of disease may be traced to a large extent from the evidences of pathology found on the fossil bones of the ancient races of man and extinct animals, as well as from the associations of the earliest animals. That early man may have acquired some of his diseases from the coexisting animals is evident from the fact that the men of the stone ages, the cave bears, and other cave-inhabiting animals were often afflicted with the same maladies, as may be seen from the diseased appearance of their bones.

It would thus seem that the relation between disease in ancient times and the extinction of great groups of animals like the dinosaurs, was a matter of minor importance. The indications of disease so far seen on ancient bones are the results of accidents, or minor constitutional disturbances which did not endanger the life of the race and seldom that of the individual. The evidence, to be sure, is scanty, being confined to that seen on the hard parts of ancient animals. But on a similar basis is erected our present extensive knowledge of the evolution of animals in past time. Many of the epidemic diseases of to-day which are so fatal to life leave no traces on the bones. It may have been so in past times, to a great extent.

The beginnings of disease are thus seen to be lost in an immense obscurity of time during which the evil forces of nature were battling with the good for supremacy. Immunity doubtless was early established, and strongly entrenched. So firmly guarded were the primitive animals of the first ages of the earth that no disturbing influences entered into their existence. Only when racial old age, and the introduction of other antagonistic influences disturbed this natural immunity did animals see the new factor of disease enter into their lives. Early land animals doubtless lived long lives of placid contentment undisturbed by fear of infection either from within or without. Disease was in its very beginnings and with the land animals spread more and more over the face of the earth as time passed on in a mighty succession of geological ages.

ZOOLOGY IN THE A. E. F.

By Dr. ROBERT T. HANCE

ZOOLOGICAL LABORATORY, UNIVERSITY OF PENNSYLVANIA

THE sudden halt in the war left approximately two million Americans stranded in Europe with the chief object of their exile and with the stimulus and the real need for work gone. It was quite obvious, whatever the temporary belief of those prevented from returning, that it would take some time to reverse the concentrated efforts to build up a mighty force in France and return the individuals to their homes. Marking time with no point in view would shortly bring discontent and disorder.

The gathering together of the large group of young men from the entire country and their subsequent examination had shown an almost unbelievable lack of uniform or satisfactory education. Indeed in far too many cases schooling had never been a factor in the individuals' lives. Clearly such conditions are not to the advantage of the nation. It was then with the intention of keeping the men engaged in work of the greatest interest not only to the nation but to themselves that the Army Educational system of the American Expeditionary Force was started. The opening paragraph of the orders (G. H. Q., A. E. F., G. O. No. 30) authorizing the opening and equipping of these schools expresses the view of the responsible officers.

> 1. The commander in chief invites the attention of organization commanders and of all officers in the American Expeditionary Forces to the importance of national education. The citizen army must return to the United States prepared to take an active and intelligent part in the future progress of our country. Educational and occupational training should therefore be provided to meet the needs of the members of the American Expeditionary Force in order that they may be better equipped for their future responsibilities.

Beyond the immediate occupation of the men in useful work the directors had in mind an experiment in national education the results of which might be of value in developing a similar plan in this country.

All grades of education were provided from primary to the highest type of academic teaching. It is with the latter that the present paper will chiefly deal. French and British uni-

versities opened their halls to Americans (chiefly college graduates) whose training fitted them for the work given but the greater need was for the continuation of the training of those soldiers whose higher professional education had been interrupted by the war. To meet this need the American E. F. University was founded at Beaune, Cote D'Or, France, a quite charming town whose inhabitants did much to make the sojourn of the Americans a thing to be remembered.

The near-by forest-covered hills and vineyards made (when the rains stopped) an exceedingly picturesque background or campus and possibilities of beautiful walks were well realized. It is the purpose of the following article to attempt to picture the development of an American educational institution of collegiate rank on foreign soil with a staff and equipment drawn almost exclusively from the army. This can be done most satisfactorily by considering the conditions met chiefly by the department with which the writer was connected and with which naturally he was most familiar, namely, the department of zoology. Beaune had been selected as the site for the university because of the location just without the town limits of an American Hospital Center which had been built in anticipation of the great drive which the Armistice fortunately prevented.

Those who arrived in February shortly after the first group had taken up their duties at Beaune found the situation far from promising. The steady rains, the poorly developed and muddy roads through the camp and the apparent general lack of preparedness were sufficient to dampen any one's enthusiasm. The complaints of many who had been ordered to teach when expecting orders home were couched in terms more generally used in the American Expeditionary Force than in America. Some were disgusted and some insulted by the conditions and state in which they found themselves. They didn't believe that much could result from Army education. One officer arrived seething after having been asked by telephone if he would come and had understood that the invitation was to give a course of lectures at the Sorbonne. The latter setting rather pleased his fancy and would look well in print at home and the collapse following the receipt of orders and the realization that his lectures must be presented far from Paris did not tend to sweeten his temper. It was frequently postulated and with some reason that the soldier student who came would be actuated more by the relief from the tedium of drill than the opportunity offered for education and that consequently the teachers would be wasting their time.

Despite pessimism operations moved ahead with remarkable speed. The draughting rooms were busy day and night drawing and blue printing plans for the subdivision of the buildings according to the desires of the departmental heads, the engineers were carrying out the work rapidly and well (the partitions being of heavy cardboard), labor gangs were turning the roads into something worthy of the name and the faculty was threshing out policy, organization, courses, ordering books and all the rest of the academic detail. Literally a complete university was to be raised from the mud and this in a hurry. Everything from buildings to equipment had to be developed in the minimum time and instructors had to be found somewhere in the American Expeditionary Force. In the interesting way in which in Army affairs the right men for certain places gradually come along a rather well balanced teaching staff was soon assembled. Illustrative of the training and experience of the faculty in general was the group that finally gathered together to teach zoology.

A. H. Bayer, B.S. (Michigan Agricultural College), private, assistant in zoology in the American E. F. University.

Wendell Lowell Bevan, B.S. (Agricultural College of Colorado), captain Field Artillery, instructor in the Agricultural College of Colorado and instructor in entomology in the American E. F. University.

Robert T. Hance, M.A., Ph.D. (University of Pennsylvania), first lieutenant Sanitary Corps, assistant in zoology in the University of Pennsylvania and chairman of the Department of Zoology and instructor in genetics and microscopical technique in the American E. F. University.

Hovey Jordan, M.S. (Harvard) first lieutenant infantry, Austin fellow Harvard Graduate School. Instructor in histology and embryology in the American E. F. University.

Homer O. Moser, B.A. (Bluffton College, Ohio), sergeant, Medical Corps, instructor in science and mathematics in the Arlington High School, Illinois and assistant in zoology in the American E. F. University.

Richard A. Muttkowski, Ph.D. (University of Wisconsin), corporal signal corps, Instructor in zoology in the Kansas State Agricultural College and instructor in elementary zoology and comparative anatomy in the American E. F. University.

Don C. Simkins, B.S. (Denison University), private first class, instructor in science in Middletown, Ohio, and assistant in zoology in the American E. F. University.

These men had largely been ordered to Beaune on the strength of the record of their previous occupation indicated on their qualification cards and made an interestingly well balanced group in regard to their zoological interests. Fortunately these men believed from the start in the practicability of the work in which they were engaged which aided greatly in speeding up the progress of development. It was interesting to note the change

in attitude that many of the early pessimists underwent as the apparent impossibilities commenced to turn into realities.

Few departments had any conception as to the desirable courses to offer and no idea as to the number of students to plan for. In zoology the courses finally agreed upon were, elementary zoology, economic zoology (this course was never given), microscopical technique, advanced zoology (in which it was planned to arrange work to meet the needs of advanced students), genetics, agricultural entomology, histology and embryology. All work, except in the last two subjects, was planned on the five hour per week basis the laboratory periods being of two hours duration. It was desired as far as equipment and supplies were available to have the courses compare favorably with similar ones in the best American institutions and in general, I believe, this hope was realized. Histology and embryology were probably quite unsatisfactory to their instructor owing to the frequent shifting of the students by the college of medicine from which the courses drew most of their members. Had the life of the university lasted for another term of three or four months it is safe to say that all courses could have been exceedingly satisfactorily presented.

The department of zoology was fortunate in being able to find much necessary equipment on the grounds in the supply depot of the hospital center. This sufficed until the larger order from the main supply depot arrived about the middle of the term. It is not an exaggeration to claim that when the latter was unpacked the department was equipped as are few zoological laboratories in American universities. The photographs of stock room and laboratories give some evidence of this. All supplies were drawn from supply depots of the United States Medical Corps and were not specially purchased for the university. Among other instruments we had large numbers of scalpels and scissors of various sizes (sufficient to equip over two hundred students at one time), about one hundred and twenty microscopes fitted with oil immersion lenses and mechanical stages (machines worth about one hundred and forty dollars apiece to-day), seventeen new microtomes, two fine balances and so on through a long list of articles.

To expedite development members of the staff manufactured many things needed ranging from blackboards to erasers, platforms and reading stands. Heavy oak tables were supplied by the quartermaster and made excellent laboratory benches. Thousands of substantial folding chairs were available. Little trouble was experienced in collecting dissecting material.

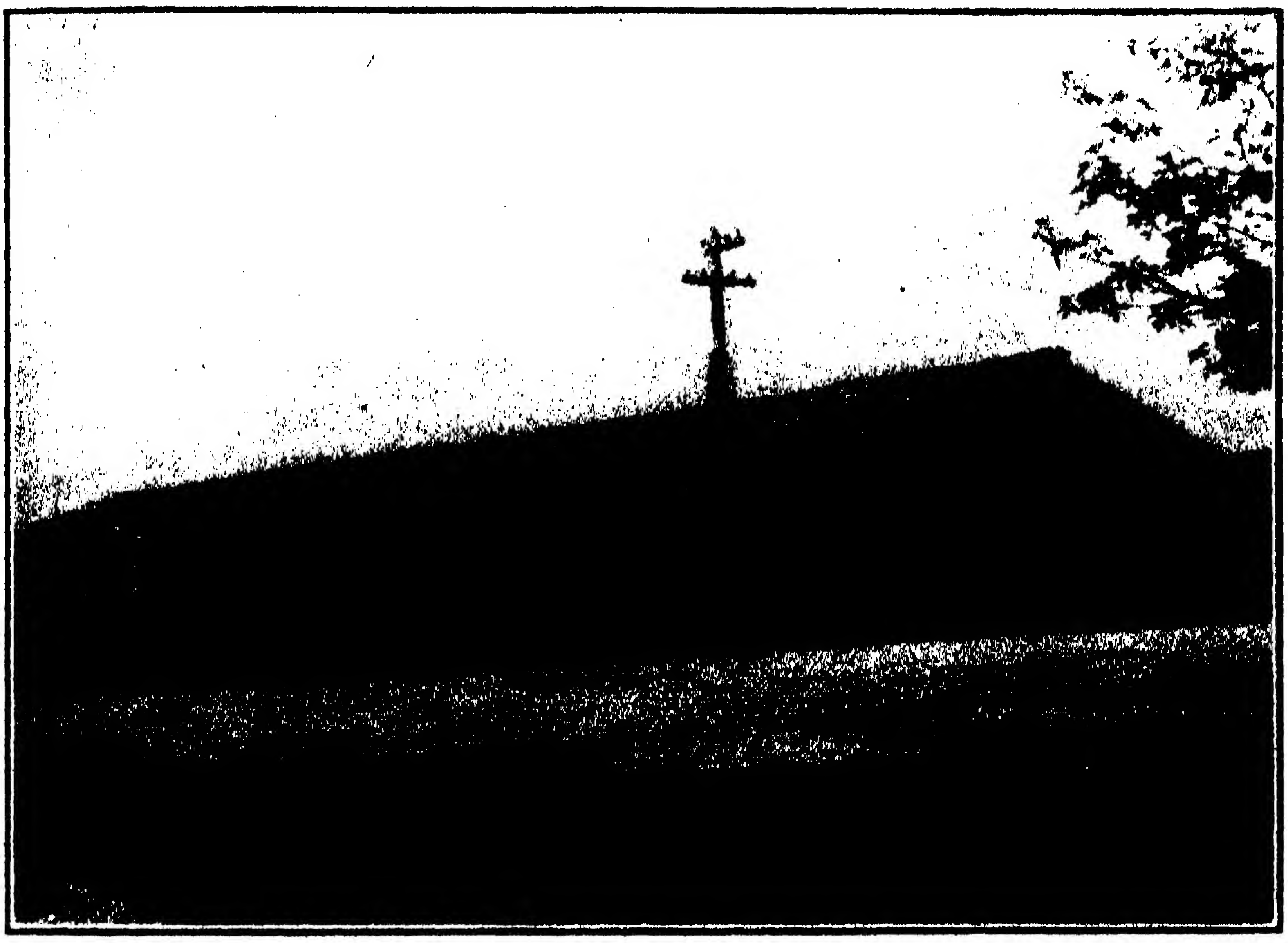


FIG. 1. THE ABOVE PICTURE ILLUSTRATES THE TYPE OF ONE-STORY CONCRETE BUILDING WHICH HOUSED THE VARIOUS DEPARTMENTS OF THE AMERICAN E. F. UNIVERSITY AT BEAUNE, COTE D'OR, FRANCE. In the above building the Departments of Botany, Psychology and Zoology were located. These structures were approximately forty feet wide by one hundred and sixty feet long.

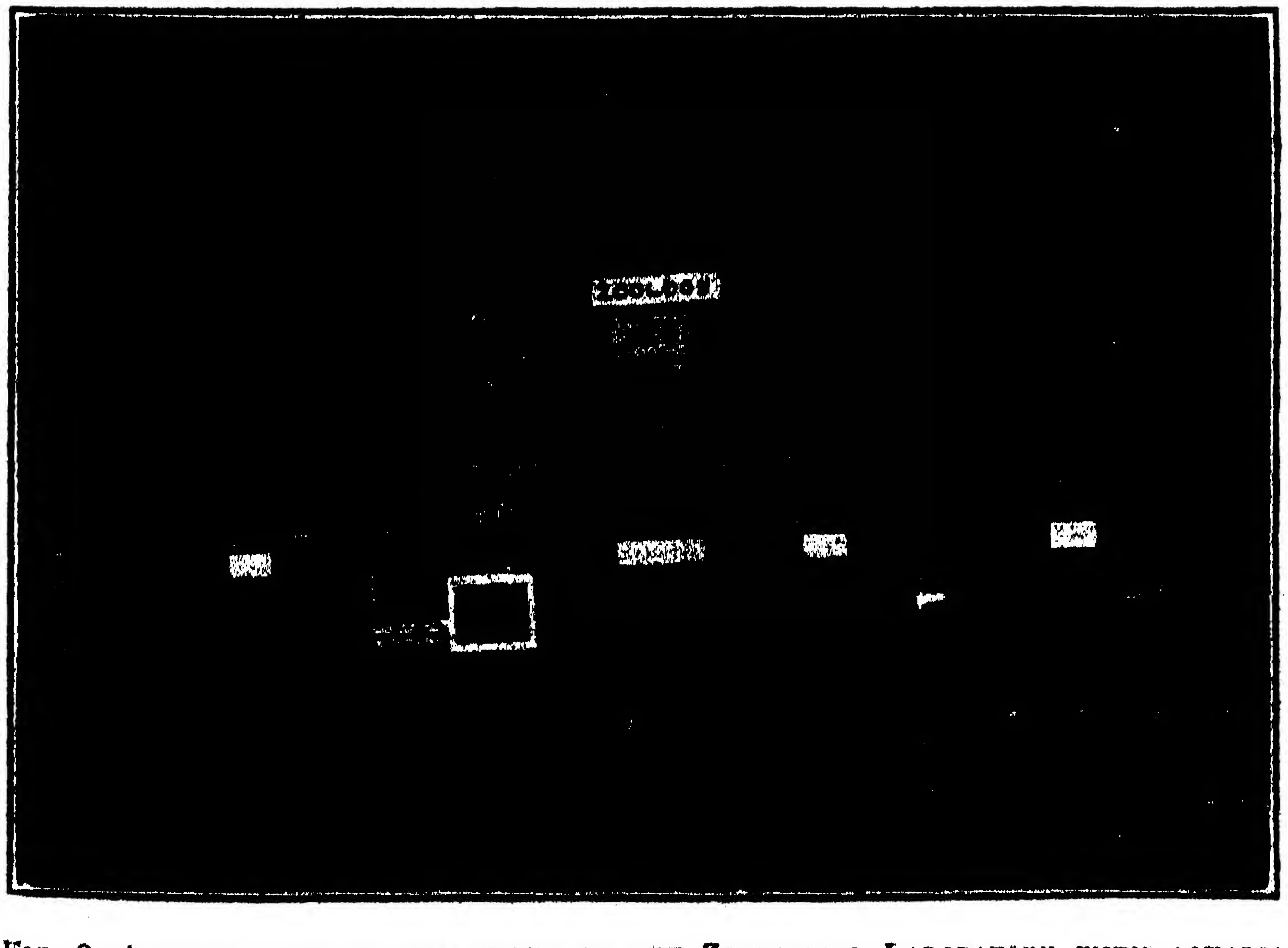


FIG. 2. A CLOSE VIEW OF THE FRONT OF THE ZOOLOGICAL LABORATORY WITH AQUARIA AND CAGES CONTAINING THE FAUNA OF THE REGION.

FIG. 3. THE INTERIOR OF THE BUILDING SHOWN IN FIG. 1 BEFORE SUBDIVISION INTO ROOMS.

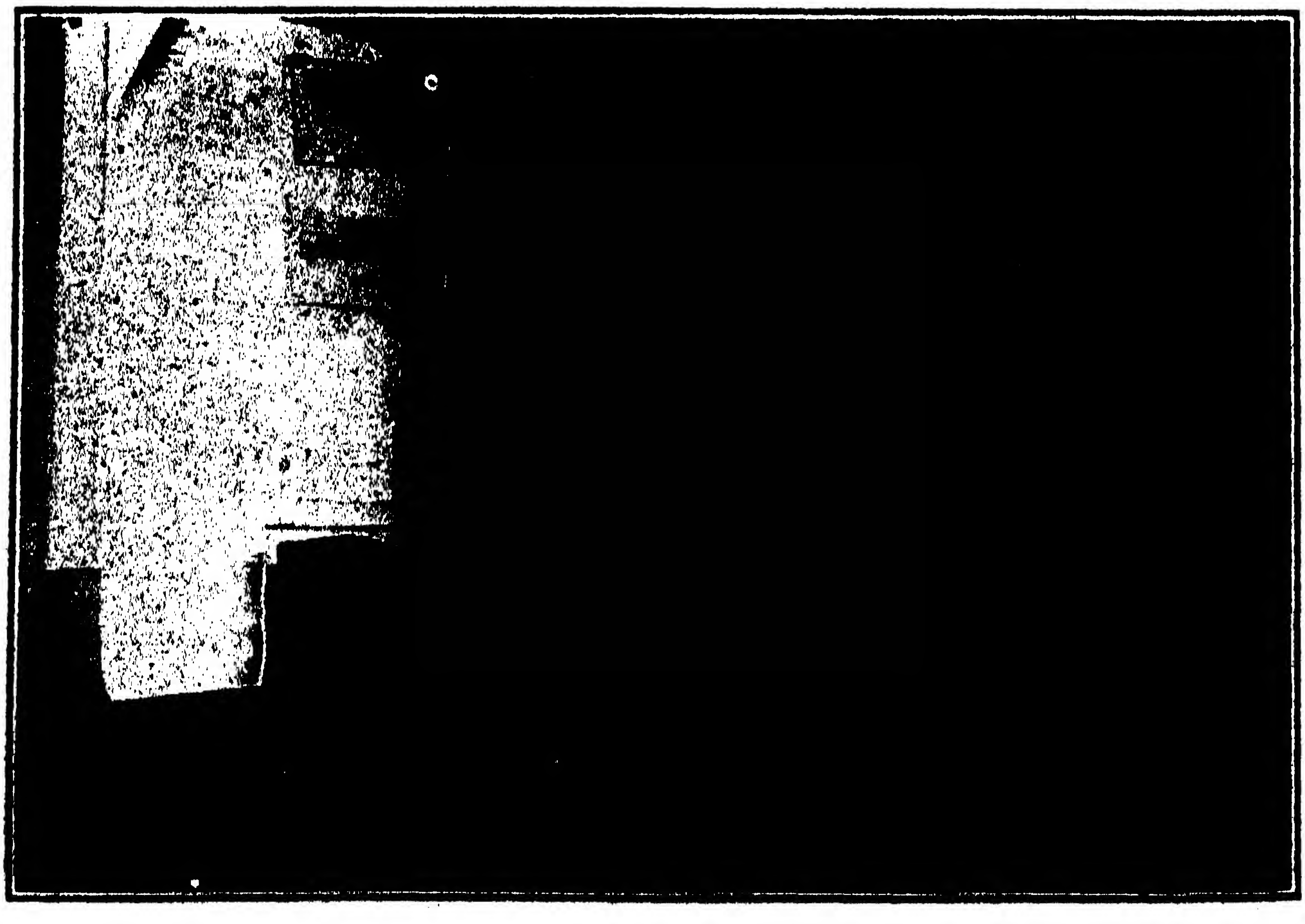


FIG. 4. THE WALLS OF THE HALL OF THE ZOOLOGICAL LABORATORY WERE COVERED WITH CHARTS DRAWN BY THE STUDENTS.

Within the confines of the camp was a large shallow pond in which great numbers of toads were spawning. It was a matter of but a couple of hours work at night to collect several hundred. Frogs were few and we did not catch more than a half dozen during our stay. The early spring with its heavy rains brought an abundant supply of big earthworms to the surface of the earth. A little later moles and mole crickets appeared in considerable numbers and were readily caught. Carp and pigeons could be bought in the game store in Beaune and there are probably few places in the world where a supply of cats and dogs are not available. Several hedgehogs were captured in

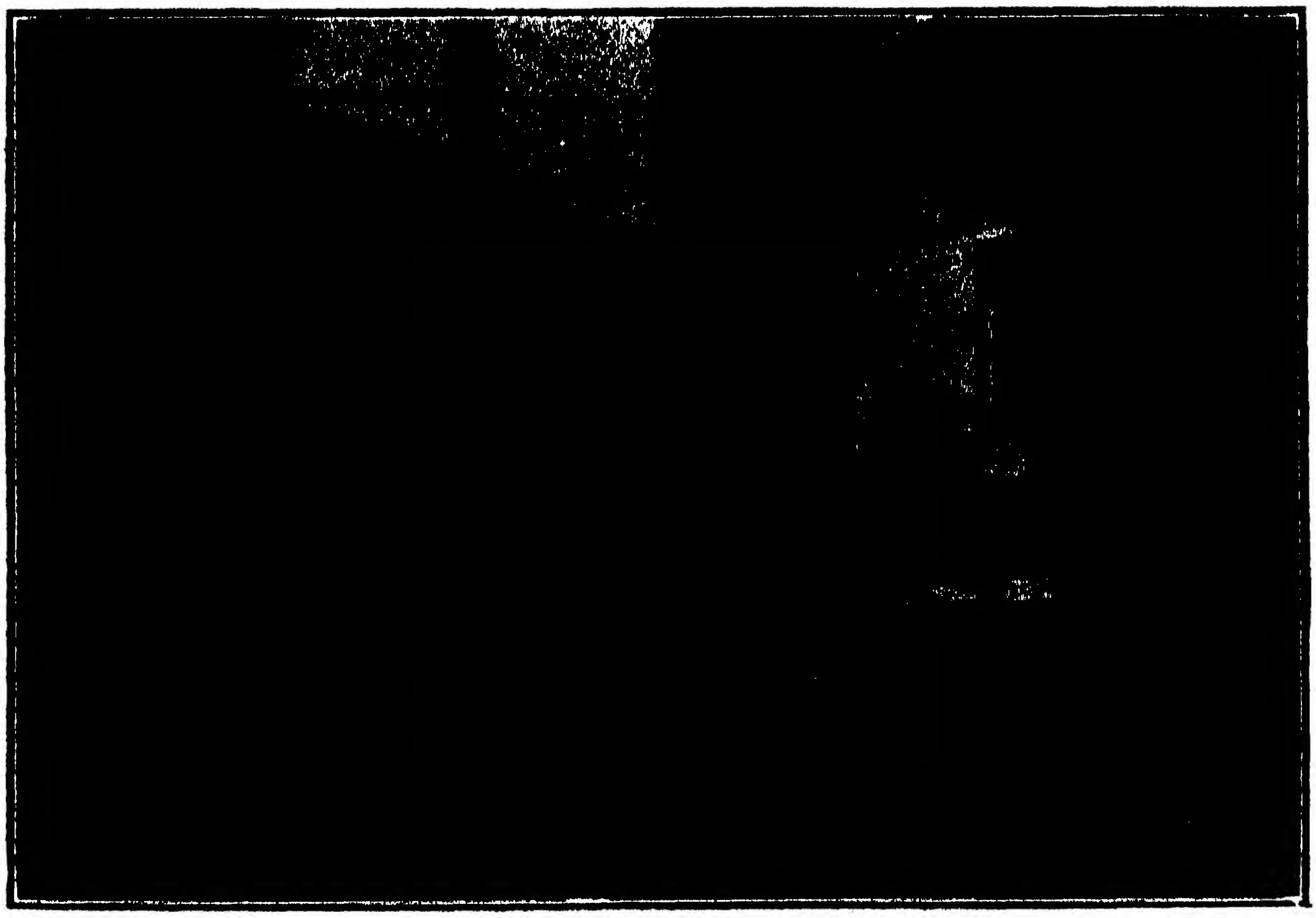


FIG. 5. A PRIVATE OFFICE.

April and May. The fauna was so interesting that shelves were put in front of the laboratory building and cages and aquaria were set up to hold the various animals brought in. Descriptions in French and English of the habits of the various forms were attached to the exhibits and this little zoo had a constant stream of visitors from early morning until late at night when I have seen would-be spectators striking matches to see what the "exhibits" were doing or to determine whether the toad and the snake still lived separately. It might be added to the credit of the snake that he at last got into the spirit of the affair and lived up to expectations. For several days thereafter the snake showed a considerable swelling in the middle of his

body suggesting the biological analogy that if base metals can not be transmuted into gold at least amphibians can be converted into reptiles.

A considerable number of excellent charts were made by certain students who preferred to put in the hour a day required in some service for the university in this manner. Since text-books in sufficient number for class use never arrived the charts were excellent teaching aids. The lack of class texts was not a serious handicap and the library was able to provide us with a number of well-known and valuable reference works which the department ordered earlier in the term.

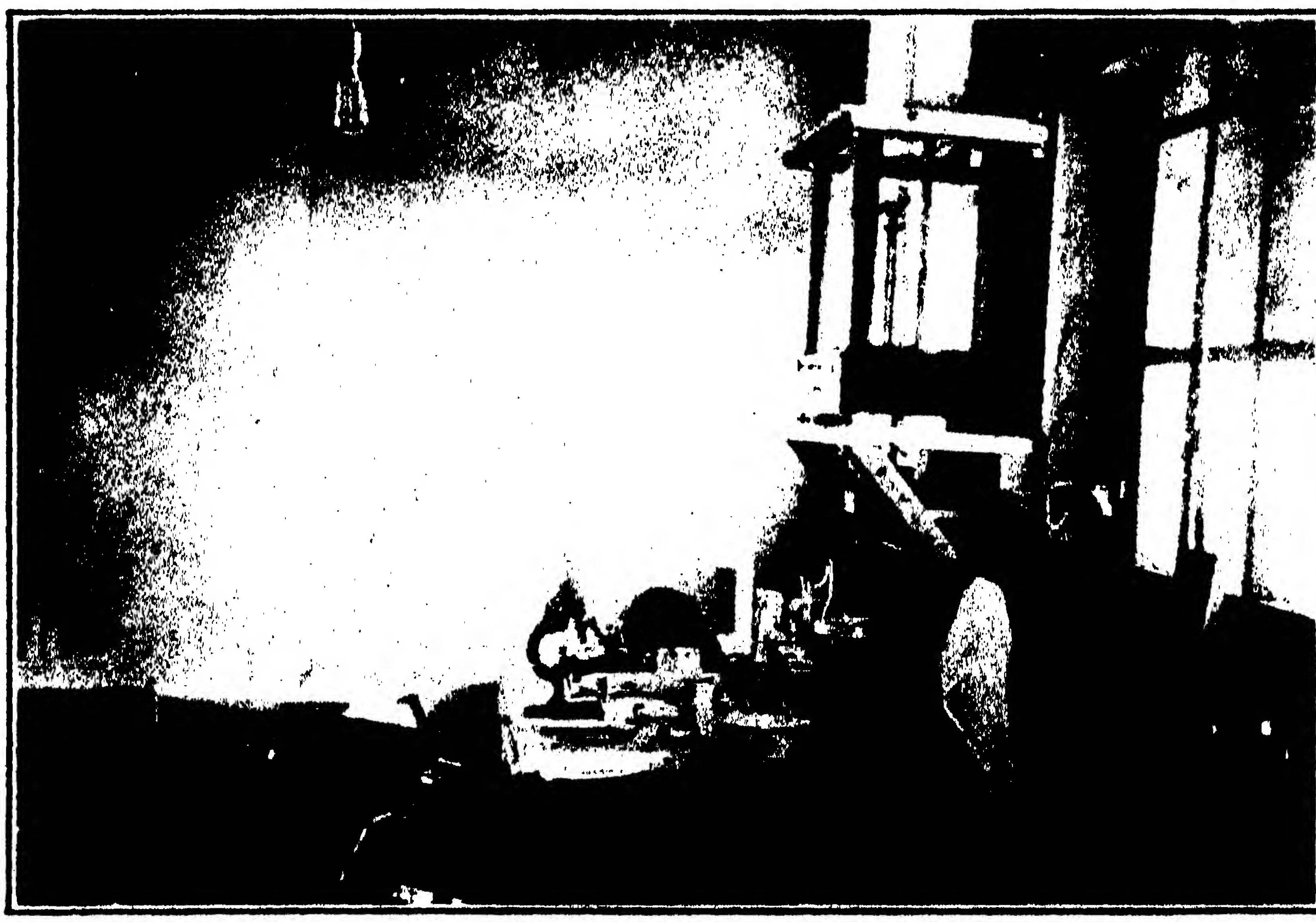


FIG. 6. A PRIVATE LABORATORY.

The largest number of students handled in the various courses was about two hundred and twenty-five, though toward the end the number was reduced to about one half through the departure of the men to join their Divisions which were returning to the States. It was the consensus of the instructors' opinions that though many of the students may have come to loaf they remained to work and that they had seldom had more interested audiences. Special lectures on the broader aspects of zoology were given in the evenings by members of the staff and attendance was voluntary and good. Though the interest and apparent caliber of the students were really high the results of the final examinations were disappointing. This it was believed might be due to any one or any combination of following

FIG. 7. A CORNER OF THE STOCK ROOM AFFORDING SOME CONCEPTION OF THE QUANTITY OF SUPPLIES ON HAND.

FIG 8. THE TOOL ROOM.

factors: the men were too recently from the unsettling conditions of war and army life to be able to take up serious and systematic study; that the little time or opportunity for evening work was possible because of the barrack living conditions and in some cases to more or less unnecessary evening inspections by certain group commanders and, lastly, the weather toward the close of the term was so delightful and such a welcome contrast to what it had been for about six months that every one wanted to be out of doors as long as possible.

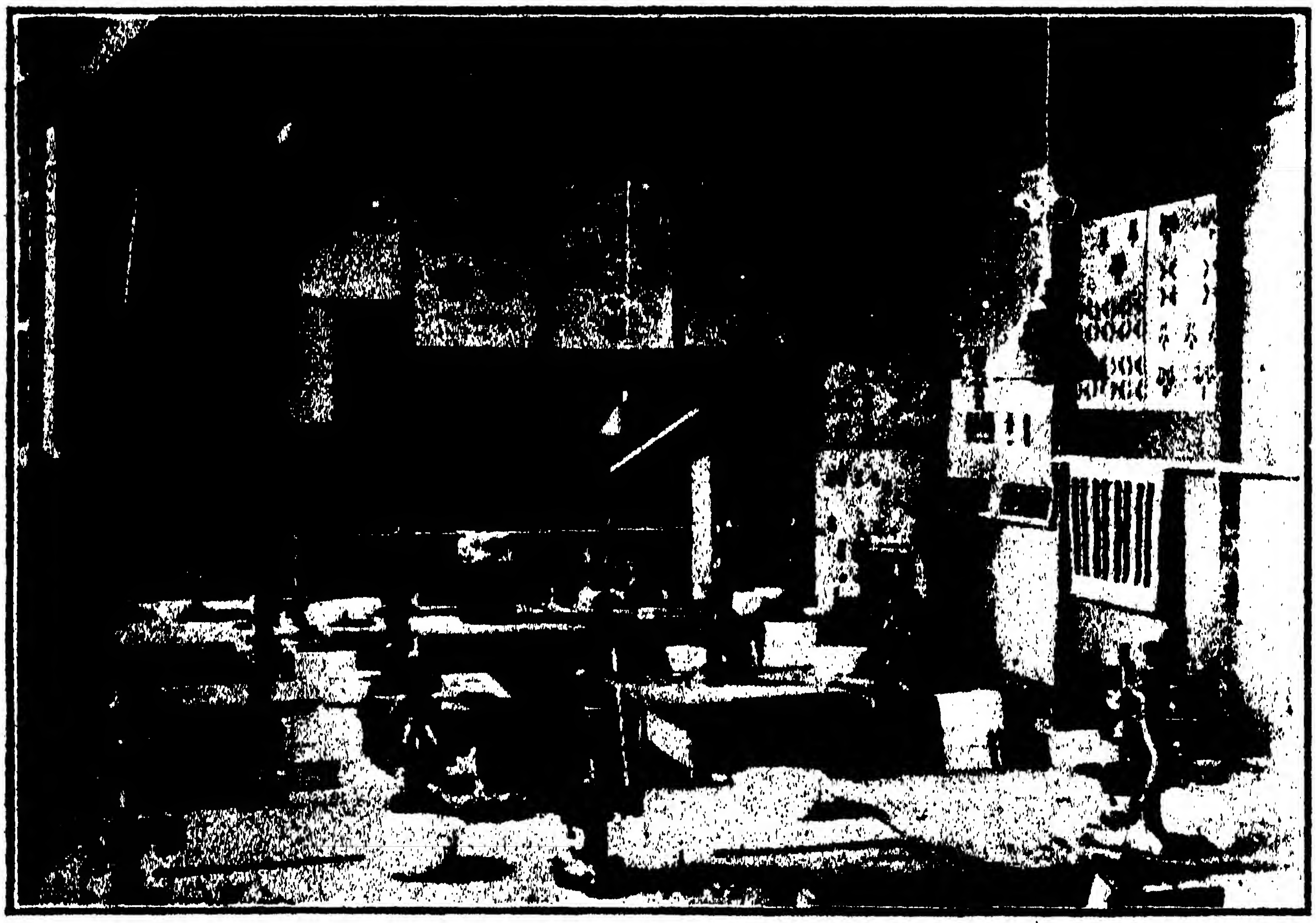


FIG. 9. THE LABORATORY OF ELEMENTARY ZOOLOGY.

A very broad policy was formulated by the university of permitting forty-eight hour week-end passes of which all could avail themselves for trips to places of interest. To nearby towns truck or automobile transportation was available for special trips. The class in elementary zoology made one such trip in trucks of about eighty or ninety kilometers to Dole, the birthplace of Pasteur. The classes in botany were able to journey into the French Alps on a collecting expedition.

It is not to be inferred though that there were not some whose work was as consistent and as good as it would have been in America. At least one individual found the subject (zoology) sufficiently fascinating to signify his intention of entering the field permanently when he returned to the United States. Others worked outside of class hours in order that they might

FIG 10. THE LABORATORY OF HISTOLOGY AND EMBRYOLOGY.

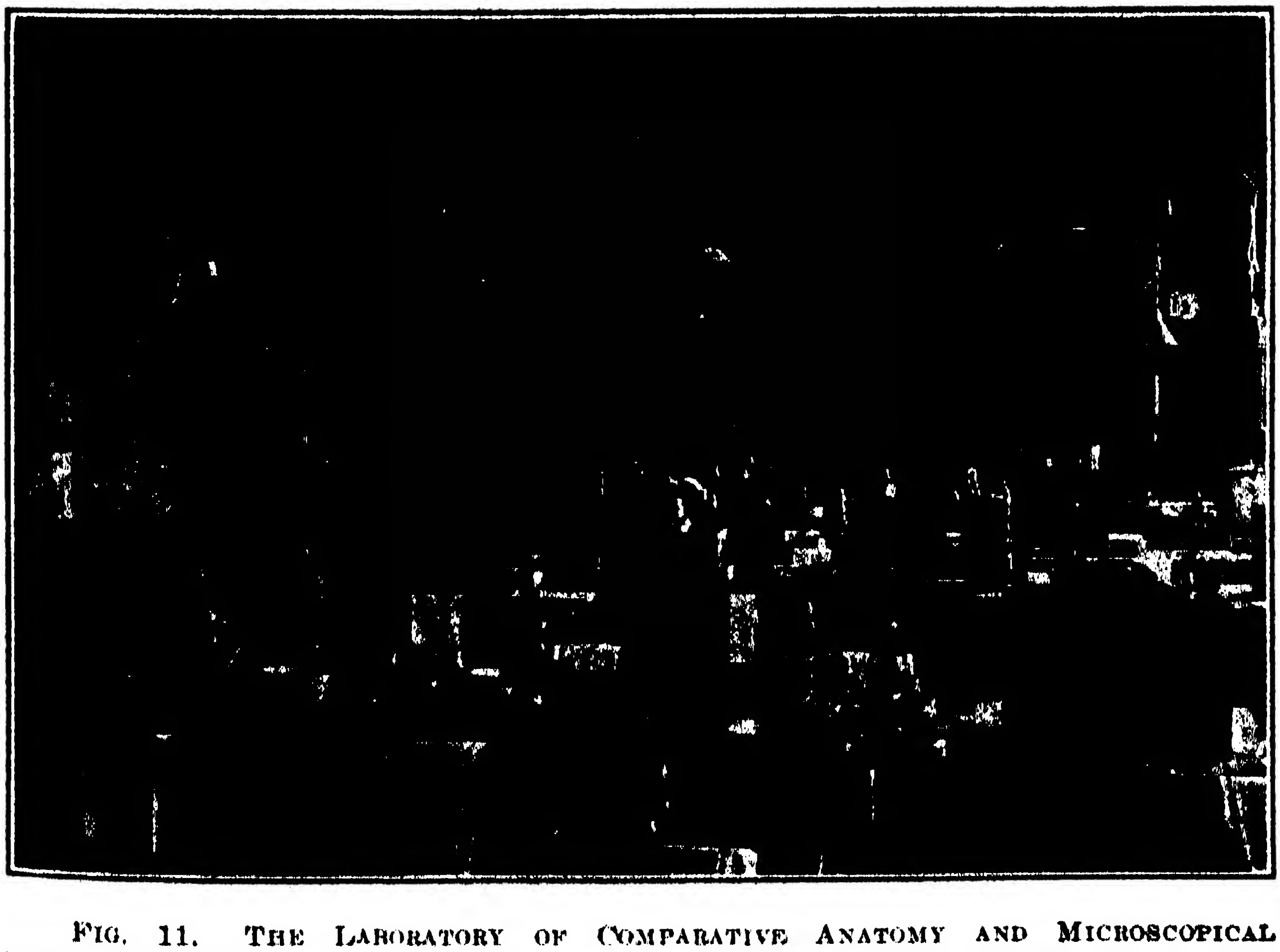


FIG. 11. THE LABORATORY OF COMPARATIVE ANATOMY AND MICROSCOPICAL TECHNIQUE. The crates to the left of the picture contain unpacked equipment, chiefly microscopes.

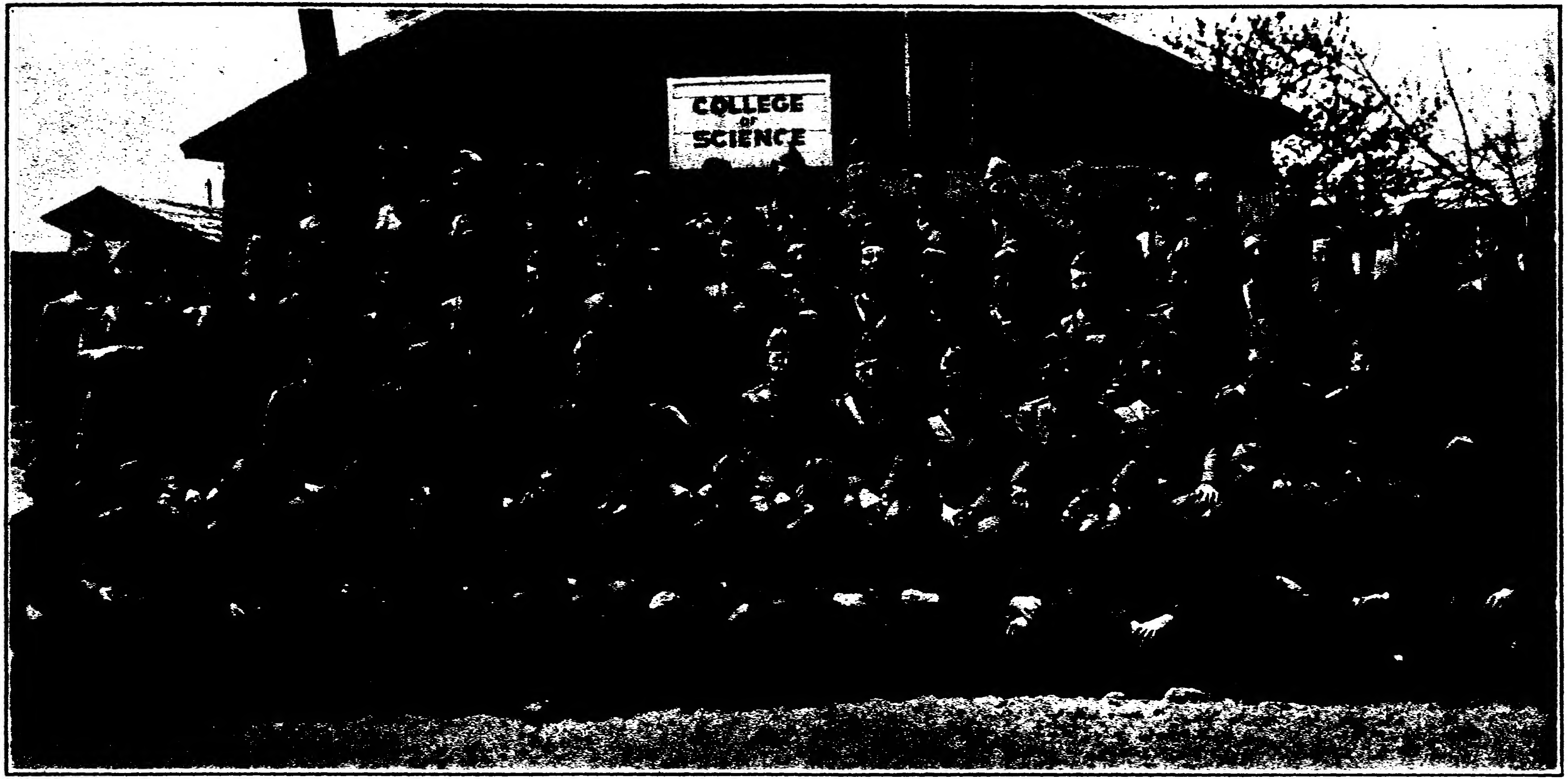


Fig. 12. The Faculty of the College of Science.

get some experience in the use of instruments and methods that they thought were going to be of value to them in the work they intended carrying on at home. If these few were really reached it is fair to conclude that the brief operation of an American University in France demonstrated its practicability since it is but a small group that we are able actually to influence in normal teaching.

FIG. 13. TRUCKS CONTAINING ZOOLOGY STUDENTS ON THE WAY TO DOLE, THE BIRTHPLACE OF PASTEUR.

That the experiment was a success I think it safe to assert. That the students at large gained in a knowledge of the general, if not always of the detailed content of the various fields of study was obvious and such being the case they could the more readily determine their reactions to these subjects and whether a pursuance of them in America would be congenial. More than this could scarcely be accomplished in the brief time available and if this was consummated the attempt at higher education in connection with the Army in France was, as claimed above, successful.

To the instructors, both commissioned and non-commissioned men, the getting back into educational surroundings and into what developed into a very fair academic atmosphere with a minimum of the military was a very delightful and a not soon to be forgotten experience. The almost complete absence of

that type of small-town, hopelessly provincial person who did so much to hurt the American reputation for fair play by refusing to admit any virtue to any foreign custom, people or scene was most cheering. Many of us had been commencing to wonder whether the vaunted broadmindedness was not a brain child of imaginative Americans. Fortunately the congregation of several hundred representative educated men completely dispelled this idea.

For the reasons indicated the writer considers the attempt to operate an American Army University in France as generally successful and a great credit not only to those leaders who built the institution but also to the American spirit of accomplishing what it starts out to do. This view recognizes the certain inherent difficulties of uniting educational work with military life and considers the difficulties to have been counteracted to a considerable degree by the uniqueness of the situation. Whether in a national scheme of militarized education the advantages will continue to outbalance the disadvantages is largely a matter of personal opinion and a subject too lengthy to permit of discussion here. Certainly though, we need a national and a standardized or uniform system of education.

THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT CARDIFF

THE British Association for the Advancement of Science held its first meeting in York in 1831. The meetings were adjourned for two years during the war and the annual meeting at Cardiff was consequently the eighty-eighth. During this long period the association has adequately forwarded its objects which are thus defined: "To give a stronger impulse and a more systematic direction to scientific inquiry, to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers, to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress."

The program at Cardiff maintained the high standards of the association, more especially in the addresses of the presiding officers and in the general discussions. The value of these addresses is shown by the extracts which the *Monthly* is able to print in its present issue, which give perhaps the best available statement of the progress and problems in the different sciences. The excellent organization of the work of the association is witnessed by the fact that through the courtesy of the speakers and the officers of the association we were able to obtain copies of the addresses in advance of their delivery.

There were 1,378 members present at Cardiff which is less than was usual before the war. Those in attendance consist largely of local associates who join for the meeting. Their fees provide a sum in the neighborhood of a thousand pounds which is annually appropriated to the committees of the association for the promotion of research, and they also supply audiences for the addresses and the meetings of more general interest and take part in the entertainment of the visiting scientific men. Owing doubtless to the different social situation the American Association has never been equally successful in enlisting the support of the people in the city in which it meets and it seems that changing conditions make it more and more difficult for the British Association to do so. Thus a correspondent writes from Cardiff that it is "rather disappointing to find the membership no greater. What is more disappointing still is that the principal reason for this is the apathy of local people of the educated classes to the presence of the association. The plain fact remains that it is the exception to find any one who has even heard of the Association."

The influence of the British Association in bringing scientific work to the attention of the country through the press seems also to be less than formerly and to be approaching the conditions in this country. In past years the London *Times* used to devote one to three of its large pages to reporting the daily programs whereas the space allotted has now shrunk to part of a page and there is a tendency to report the papers on social and educational subjects rather than the results of research in the natural and exact sciences.

The meetings of the British Asso-

PROFESSOR WILLIAM ABBOTT HERDMAN

President of the British Association and Professor of Oceanography in the University of Liverpool. The drawing of the Portrait has been kindly supplied by the Editor of the *Evening Transcript*.

ciation correspond more nearly to those of the American Association prior to the past twenty years. Our association then held its meetings in the summer, and excursions and entertainments were emphasized, which led to a larger attendance of amateurs and perhaps to more local interest. The American Association has now become primarily an association of societies rather than of individuals. No other country holds meetings at which so many scientific men are in attendance or at which the special programs of scientific papers are so extensive. It may, however, be that the more technical organization of the meetings has led to giving less attention to the work of bringing scientific research and its importance for the nation to the attention of a wider public. In a democracy science must depend on a wide appeal for its support and for recruits. The situation in England indicates the increasing difficulties as science becomes more highly specialized and scientific men become more completely absorbed in their special work. It should, however, be possible to apply scientific methods not only to scientific research, but also "to obtain a more general attention to the objects of science."

Professor W. A. Herdman is succeeded in the presidency of the association by Sir Edward Thorpe, emeritus professor of chemistry in the Imperial College of Science, London. The meeting next year will be at Edinburgh.

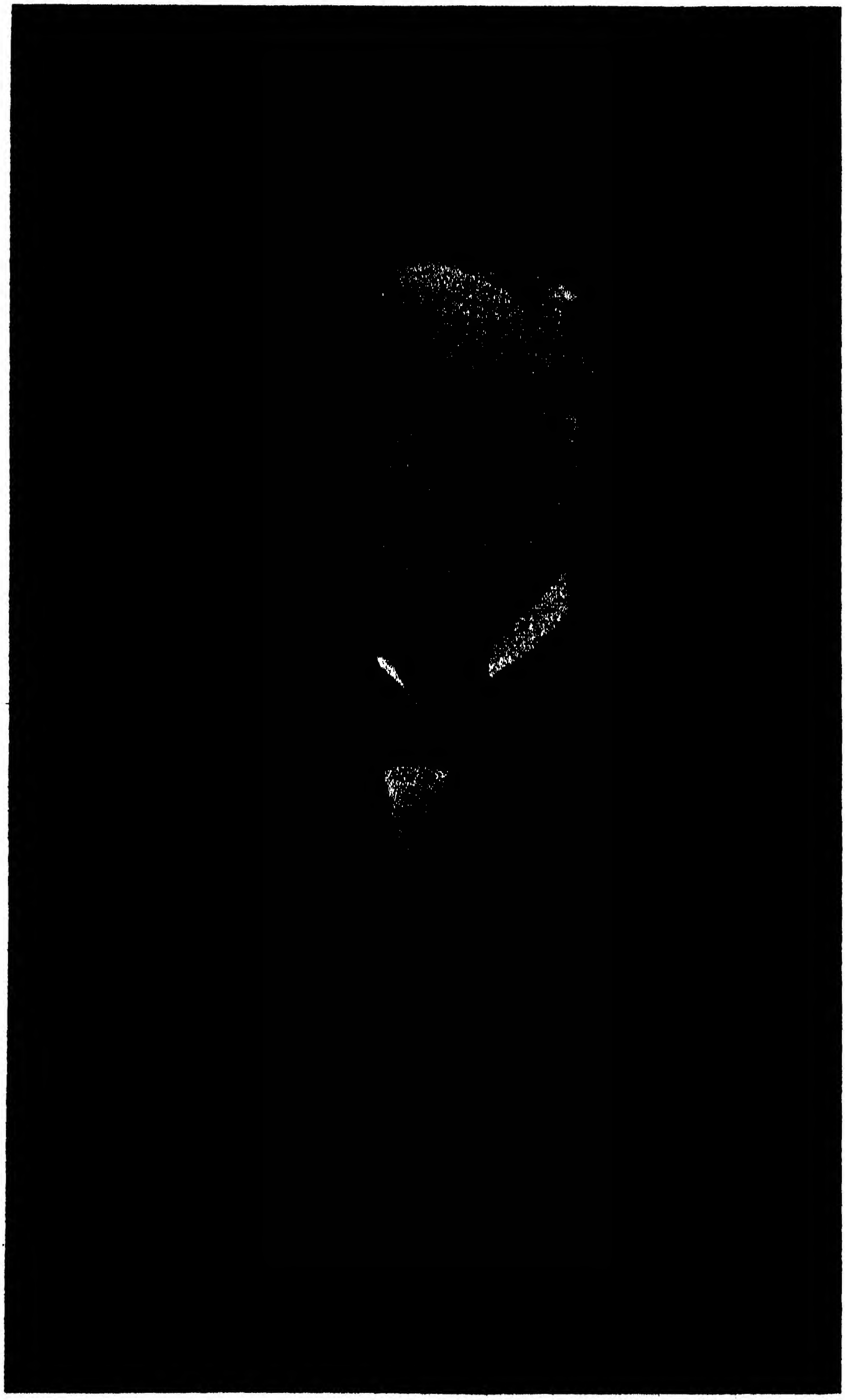
THE SCIENTIFIC INVESTIGATION OF THE OCEAN

As an example of the discussions at the meetings of the British Association that before the section of zoology on the need for the scientific investigation of the ocean, as reported in *Nature*, may be taken. Dr. W. A. Herdman, the president of the meeting, is professor of oceanography at Liverpool and his address on this subject naturally led to a fuller discussion with a practical object in view.

In opening the discussion, Professor Herdman pointed out the need of investigation under two heads—the scientific need and the industrial. He proposed that there should be a great national oceanographical expedition—that is, another *Challenger* expedition, fitted out by the British Admiralty, and embracing all departments of the science of the sea investigated by modern methods under the best expert advice and control. Such an expedition would require long and careful preparation, so even though the present time may seem to some inopportune to press such an undertaking, if this suggestion is received with favor by oceanographers, it might be wise to form a preliminary committee to collect information and prepare a scheme.

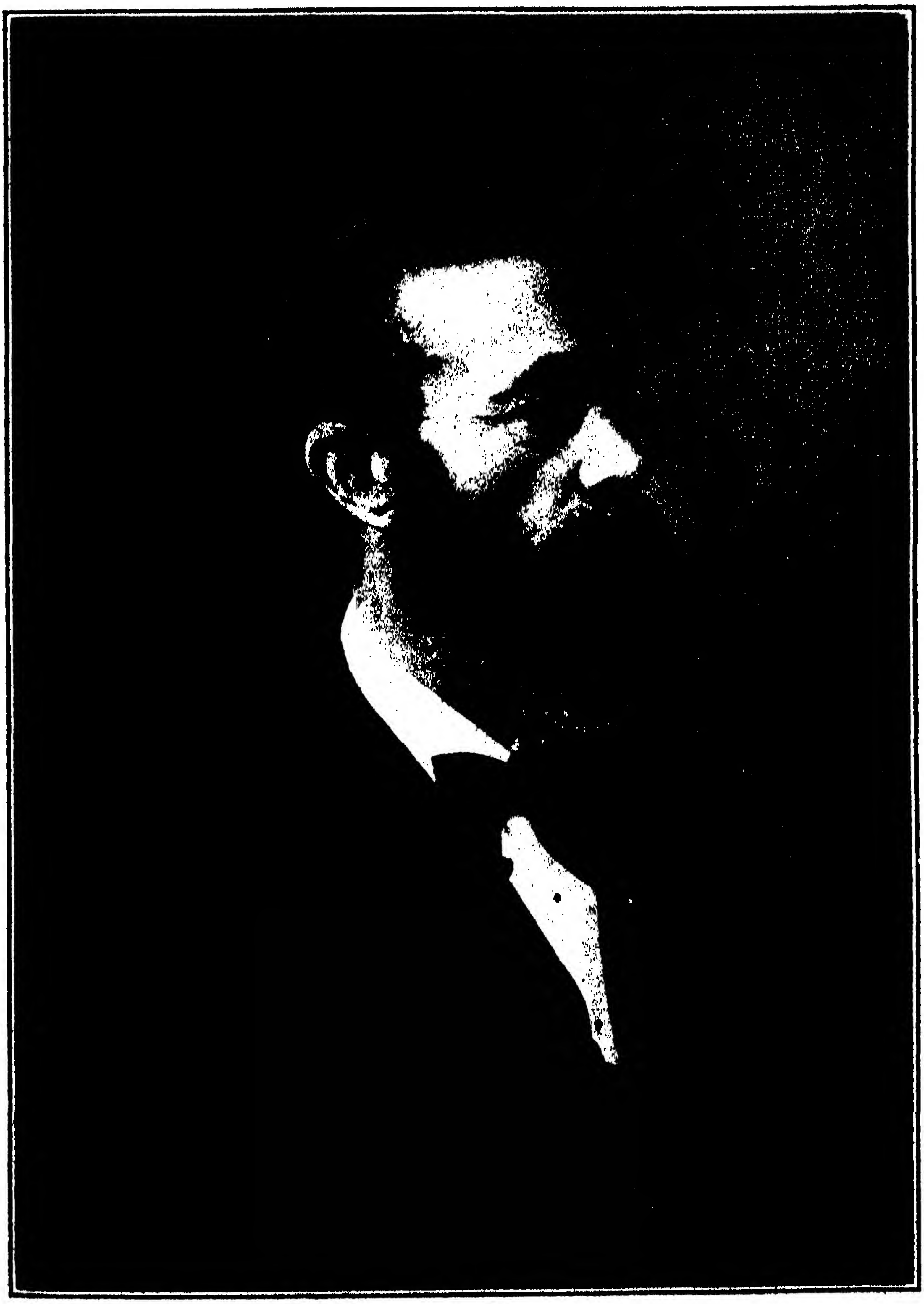
In the further discussion Professor J. Stanley Gardiner, Dr. E. J. Allen, Mr. C. Tate Regan and others took part, including Professor C. A. Kofoid from the United States and Professor J. E. Duerden from the Union of South Africa. Mr. F. E. Smith, director of scientific research at the admiralty, stated that his department had considered the question of a new *Challenger* expedition, and was of opinion that such an expedition was required, and he felt sure that the admiralty would take its share in the organization.

At the close of the discussion a resolution was unanimously agreed to pointing out the importance of urging the initiation of a national expedition for the exploration of the ocean, and requesting that the council of the British Association should take the necessary steps to impress this need upon the government and the nation. On the following day, at the committee of recommendations, this resolution also received vigorous



JAMES WILSON

Secretary of Agriculture in the cabinets of Presidents McKinley, Roosevelt and Taft, previously professor of agriculture in the Iowa State College and director of the Experiment Station, who died on August 26, at the age of eighty-five years.



WILHELM WUNDT

Professor of philosophy in the University of Leipzig, leader in the foundation of psychology as a science, who died on August 31, in his eighty-ninth year.

support from other sections, *e. g.*, those dealing with chemistry, physics, geology, and geography, in all of which, as well as in zoology, investigations are required which could be undertaken by such an expedition. The general committee of the association recommended the council to appoint an expert committee to prepare a program of work and to consider the personnel and apparatus required.

At its last two meetings the Pacific Division of the American Association has given special attention to deep-sea investigations and further emphasis was placed on the subject by the Pan-Pacific Conference held last month at Honolulu. It would be desirable in the present international situation for the United States to cooperate with Great Britain and its Dominions in a thorough scientific exploration of the seas.

SCIENTIFIC ITEMS

WE record with regret the deaths of Joseph Paxon Iddings, formerly geologist of the United States Geological Survey and professor of petrology in the University of Chicago; Samuel Mills Tracy, agronomist of the United States Department of Agriculture; Dr. Walter Faxon, until recently in charge of mollusca and crustacea in the Museum of Comparative Zoology of Harvard University; Ellis L. Michael, zoologist of the Scripps Institution for Biological Research of the University of California; Benjamin Smith Lyman, geologist and mining engineer of Philadelphia; John Percy, professor of mathematics at the Royal College of Science, London; Sir Norman Lockyer, director of the Solar Physics Observatory, London, and editor of *Nature* from its establishment over fifty years ago, and Wilhelm Wundt, professor of philosophy at the University of Leipzig, where he established the first laboratory of psychology.

DR. GEORGE ELLERY HALE, director of the Mount Wilson Observatory, has been elected one of the twelve foreign members of the Società Italiana delle Scienze, in succession to the late Lord Rayleigh.—Professor Raymond Pearl, of the Johns Hopkins University, has been decorated by the King of Italy as Knight of the Crown of Italy.—Professor R. Roux, director of the Pasteur Institute at Paris, has been awarded by the United States government the Distinguished Service Medal for especially meritorious and distinguished service which was of great consequence to the American Expeditionary Forces.

COLONEL F. F. RUSSELL has resigned from the Medical Corps, U. S. Army, to take charge of the newly organized Division of Public Health Laboratories of the International Health Board of the Rockefeller Foundation. — Dr. Charles Hubbard Judd, head of the department of education of the University of Chicago and director of the school of education, has been made chairman of the department of psychology to succeed Professor James R. Angell, who resigned to accept the presidency of the Carnegie Corporation of New York.

YALE UNIVERSITY has received from an unnamed graduate a gift of $3,000,000 to the general endowment of the university, contingent upon additional gifts of $2,000,000 by next January, exclusive of those through the alumni university fund. The gift is made to meet increased faculty salaries.—Cornell University has received a gift of $500,000 from Mr. August Heckscher, of New York City, for the endowment of research. The income of the fund created by Mr. Heckscher's gift will be used to maintain research professorships and to provide facilities for scientific work.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1920

THE RÔLE OF PHYSIOGRAPHY IN MILITARY OPERATIONS[1]

By KIRK BRYAN

UNITED STATES GEOLOGICAL SURVEY

INTRODUCTION

STUDY of the terrain is an essential preparation for military operations. Under terrain, students of military science include all the features of the land surface, whether natural or artificial, which affect the movements and disposition of troops either on the offensive or defensive. The relative importance of the terrain in a military problem varies obviously with respect to other factors, such as the strength, disposition, and morale of both enemy, and friendly troops, and the proportion of infantry to the other arms present. It may be safely assumed that the terrain will enter into the solution of nearly every military problem. The features of the land surface under various names, such as topography and land form, are the principal study of the modern school of physiographers and geographers. Physiographers are concerned with the origin of the topography of the earth's surface; geographers with the relation of this topography to the habits and character of man. The methods and results of these scientific inquiries into the nature of topography may, however, be readily adapted to the needs of military operations. This relation between physiographic and military science was first recognized by the French, though their use of physiographic material in the late war was subconscious rather than conscious.[2]

[1] Published by permission of the Director of the United States Geological Survey.

[2] Brooks, Alfred H., "The Use of Geology on the Western Front," U. S. Geol. Survey, Contrib. to General Geol. Prof. Paper. In press.

Marga, A., "Géographie Militaire," 5 vols. and atlas, Paris. 1884–1885.

Where operations are on a large scale, neither the responsible general officers nor line officers have sufficient time or opportunity for detailed study and analysis of the terrain. They must rely for information on the maps and reports of others. The preparation of these reports, in so far as they pertain to terrain only, can best be done by geologists trained in physiography. The same methods and observations which they are accustomed to make for scientific studies serve equally well for military purposes.

The preceding generalizations have resulted from my service in the late war, and the following paper divides naturally into two parts: (1) a personal account of the use of physiography in actual operations; (2) suggestions for the application of physiographic information and for the utilization of geologists in the future.

The preparation of the paper has been greatly facilitated by the generous and constructive criticism of Mr. A. H. Brooks, formerly Lieutenant Colonel, Engineers, and chief geologist, A. E. F., Major Lawrence Martin, G. S., Lieutenant Colonel A. M. Prentiss, C. W. S., and Messrs. N. C. Grover, H. G. Ferguson, Sidney Paige and John S. Brown.

Experiments in the Use of Physiography

Organization of the 5th Army Corps

Through the operations of the Selective Draft, I found myself on June 30, 1918, a private in Headquarters Detachment of the 5th Army Corps. An army corps is the administrative unit which supervises three or more divisions and is, in turn, subordinate to the army. The newly organized 5th Corps had headquarters at this time in Remiremont, Vosges, and the commanding general had administrative but not tactical control of two divisions which were in training under a French Corps commander on the Alsace Front. The headquarters staff was divided into three sections, of which the second, known as the Intelligence Section, or simply G–2, had to do with information regarding the enemy, morale behind the lines, and counter espionage. Colonel George M. Russell, a regular army officer, was in command of this section of the Staff consisting of 12 officers and 59 enlisted men. Maps, map-making, and drafting for the corps were handled by a subdivision of G–2 called the Topographical Section, or G–2–C, in which I was enrolled as a

Barré, O., "Cours de Géographie, and Croquis Geographique, l'école d'application de l'artillerie et du genie," Fontainebleau, 1897–1900.

draftsman. Lieutenant Reuben A. Kiger, a topographical engineer of much experience on the United States Geological Survey, was in charge, and later he was assisted by Lieutenant R. B. Holmes.

My time for the first month was occupied in improving my technique in drafting and in learning the routine of Corps procedure. The officers of the Corps were also engaged in adjusting themselves to their new duties and not the least of their problems was to learn the use of maps. Largely recent civilians, lawyers, business men and engineers, they had paid little attention during their early education to topography and maps. Their army training was so brief and crowded that these studies had seemed less important than infantry drill and army paper work. Colonel Russell with his West Point training and Lieutenant Kiger and Lieutenant Holmes with experience on the Geological Survey were quite exceptional in starting in on Corps duties with an adequate knowledge of maps. While frankness compels us to admit this serious deficiency, one should bear in mind the remarkable achievements of this organization. The French consider that the building up of a Corps Staff is a matter of years yet the 5th Corps within two months of its organization began the successful St. Mihiel drive and two weeks later formed the center of the line in the Argonne in one of the most stubbornly fought engagements in history.

At the close of the St. Mihiel drive, the Corps had settled down in its routine work and a very keen appreciation of the value and use of maps had arisen. The Topographic Section was now called on for maps of many different scales and for many different purposes.

Block Diagram of the Argonne Region

The first rush of the Argonne offensive, beginning September 26, was remarkably successful. But because of increasing resistance and our inability to bring forward artillery fast enough, we were hung up before Cierges from September 28 to October 4. Again from October 5 to 8 we were stalled near Gesnes, by the outpost defenses of the Kriemhilde Stellung. The First and Third Corps on either side were in similar difficulties.

Many of our troubles arose from lack of appreciation of the terrain. Around Corps Headquarters many officers did not seem to have an adequate conception of the country in which the Corps was fighting, nor its relation to contiguous territory.

This impression, based on the gossip of Headquarters available to enlisted men, seemed to reflect a state of mind prevalent throughout the whole organization. Divisions and smaller units had of course even less information than we had, but had the advantage of seeing the country immediately in front of them. Lack of appreciation of topography was general and, while excusable, a condition which could be easily remedied.

A number of our officers had read D. W. Johnson's book on "Topography and Strategy of the War" and they testified that it had given them an invaluable conception of the topography of the theater of war in France. I could not, of course, judge of the correctness of Johnson's views on strategy, but his method of presentation is excellent. His topographic description is based on the best physiographic information and is built around and constantly refers to a simple block diagram of eastern France. Accordingly, I began work during time free from other duties, on a block diagram of the Argonne Region, similar in style to Johnson's diagram of eastern France.

The diagram is reproduced in Fig. 1, having been redrawn and slightly modified to conform with the detailed geologic maps now available. At the time, the only source of information was a school atlas of France. The text, reproduced below, has also been altered to conform more nearly to my present conception of what such a topographic description should be. The diagram and text are, however, essentially the same as when they were issued as a supplement to the Corps Summary of Intelligence. It will be noted that there is no discussion of strategy or tactics, which are not considered to be within the province of the Intelligence Section.

Military Topography of the Argonne Region

The Argonne Region as a field for military operations has certain striking topographic features. The Argonne and adjacent territory from our front line northward consists of six distinct belts of country. As shown in the block diagram attached, these regions, beginning at the west, are: (1) Escarpment of the Dry Champagne (Champagne Pouilleuse), the crenulated edge of a plateau; (2) Aisne Valley (Champagne Humide), a lowland; (3) Forêt d'Argonne, a rugged ridge; (4) Aire Valley, a flat-bottomed valley with rolling country on the east; (5) Côte de Meuse, a deeply incised plateau; (6) Wovere Plain, a lowland. The topography of each of these regions is carved from the underlying rocks which form the rim

of the Paris Basin. These rocks are great sheets of limestone and shale which dip gently beneath the ground to the west and southwest like the edges of a nest of saucers with Paris in the center. Each bed of limestone forms a ridge with an abrupt slope on the east, and a gentle westward slope. The shales form lowlands between the ridges. The ridges thus formed are: (1) Escarpment of the Dry Champagne; (2) Forêt d'Argonne; (3) Côte de Meuse.

FIG. 1. BLOCK DIAGRAM SHOWING THE RELATION OF TOPOGRAPHY TO GEOLOGY AND TO MILITARY OPERATIONS IN THE ARGONNE REGION.

The Escarpment of the Dry Champagne is about 60 meters high, and is in many places cleared and cultivated, yet the branching ravines which indent the border of the escarpment and drain eastward to Aisne River afford excellent cover for artillery. The rough country yields many places suitable for local strong points. The effectiveness of this topography for defensive operations is shown in the recent resistance of

the enemy on the line Monthois-Livry-Orfeull, west of Challerange.

The Forêt d'Argonne ridge rises 100 meters above the adjacent valley of the Aisne. It is much higher and more rugged than the Escarpment of the Dry Champagne. The scanty soil and steep slopes have led to its being used almost exclusively as timber land and there are few clearings and few roads. The ridge is divided by the valley of the Aire River at Grandpré. North of this gap it is not so bold or conspicuous and gradually fades out into isolated wooded hills in the vicinity of Attigny.

The Côte de Meuse lies parallel to the Forêt d'Argonne at a distance of 25 to 30 kilometers. The eastern border of this plateau is a particularly bold escarpment rising about 250 meters above the Woevre Plain. Against the eastern face of the plateau the waves of the German advance broke in 1914. The canyon of the Meuse River divides the ridge diagonally between Verdun and Dun-sur-Meuse. The serpentine bends of this flat-floored canyon prohibit its use as a ready means of advance across the ridge, yet the sharp bends and projecting spurs prevent long-range observation and render sections of the canyon, once occupied, of great value for the location of supply lines. The tributaries of the Meuse entering from east and west have cut sharp ravines in both walls of the canyon and converted the plateau into a succession of cross-ridges. Over these ridges and astride the river the Crown Prince advanced in his assault on Verdun. In turn, over the same successive ridges, the Allies are now advancing northward. The advantage of topography is, however, with the Allies, for the Côte de Meuse decreases in height toward the north and fades out into isolated hills and ridges at la Bar River.

The lowlands of the regions are: (1) The Aisne Valley; (2) The Aire Valley (from Varennes to Buzancy); (3) The Woevre Plain.

The Aisne Valley, or more properly the Valley of the Upper Aisne, is the northern representative of the Wet Champagne. The soil is clayey and tends to be boggy in wet weather.

The district from Varennes to Buzancy may be considered as a lower belt of country between the Forêt d'Argonne and the Côte de Meuse, or as the lower slope of the latter ridge. It is bordered on the west by the valley of the Aire River. This valley is narrow from Varennes to Grandpré, but north of the Grandpré a similar but broader lowland extends northward to the pass east of Attigny. East of the Aire valley, the country is a rolling plateau drained by streams which flow west to Aire

River in rather broad, smooth valleys, and by streams which flow eastward to Meuse River in narrower, steeper valleys and ravines. The interstream areas are broad and smooth, and rise to similar elevations except for isolated hills or groups of hills which stand as knobs on the generally smooth upland. Such knobs are the hills at Vauquois and Montfaucon and the clump of hills southwest of Romagne-sous-Montfaucon. The woods are usually located on the divides and isolated hills. Offensive operations in such a country consist in the taking of one east-west ridge after another. Possession of the wooded ridge crests and the isolated hills gives the best observation posts and largest field of fire. That these features are thoroughly appreciated by the enemy may be seen in the skill with which the Kriemhilde Stellung has been located so as to take full advantage of this topography.

The Woevre Plain, underlain by soft and impervious shales, has two primary characteristics: It is very flat, and very muddy in wet weather. The plain, however, narrows rapidly north of Verdun, and from Stenay northward gradually disappears in the gently-rolling country of the pass of the Sedan. Once the Côte de Meuse is completely held, the Woevre Plain forms no obstacle to an advance into Sedan.

The pass of Sedan lies between the ridges previously mentioned and the rough mountainous country called the Ardennes. Traffic from the east follows the valley of la Chiers River. West of Sedan the Canal d'Ardennes runs southwestward up the valley of la Bar River, and then over a low divide to the Aisne River at Attigny. The pass of Sedan, comprising the valley of the Meuse from Sedan to Mezières, is the route along which runs the main line railroad Metz-Conflans-Longuyon-Montmedy-Sedan-Mezières. This portion of the railroad is the central section of the great "ligne de rocade" which parallels the German front in the west, and over which troops are shifted laterally along the line. The cutting of this line at Sedan is topographically practicable once the Forêt d'Argonne and the Côte de Meuse are held.

The Attack of November 1, 1918

From October 8 to October 16 our Corps was occupied with the slow and painful assault on the Kriemhilde Stellung, which ran among the wooded hills southwest of Romagne-sous-Montfaucon. This German defense position had been provided with wire but the trenches had only been marked out and not dug to

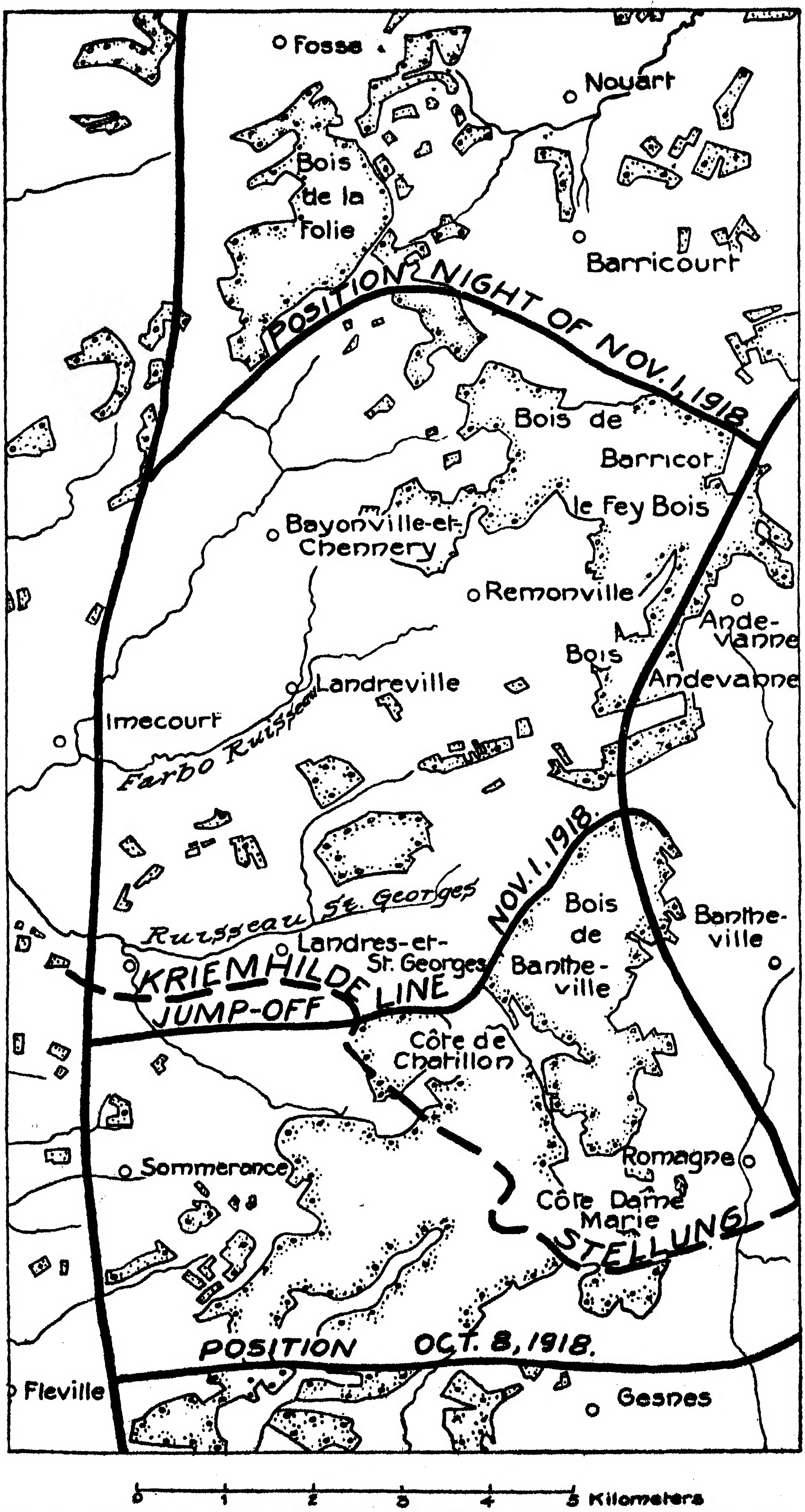


FIG. 2. ZONE OF ADVANCE OF THE 5TH ARMY CORPS IN THE ATTACK OF NOVEMBER 1, 1918.

the full depth. The Kriemhilde Stellung was then not a complete trench system but a previously selected retirement position which was rather hastily converted into a deep zone of machine gun positions and rendered very serviceable because the high hills gave good observation of our preparations for attack. Wood by wood, and hill by hill, these positions were gradually taken. By October 21, our Corps front lay in front of the wire south of Landres-et-St. Georges and thence swung northeast along the border of the Bois de Bantheville. The local and general situation being ripe, a general assault was ordered for the morning of November 1, 1918. For this successful attack most elaborate preparations were made and the maps produced by G–2, 5th Army Corps, are so complete and well designed that they are likely to become a classic example of good practice.

On the evening of October 30, Lieutenant Holmes gave me orders to prepare a report on the streams which lay in front of our positions, and which might prove an obstacle to our advance. There was no information available regarding these streams except that shown on the Plan Directeur, a map compiled by the French on the scale 1:20,000. The Water Supply Report on the area issued by the Chief Engineer gave no particulars of these minor streams. However, this seemed to be an opportunity to describe the valleys even if there was no information about the streams. The area to be covered, shown in Figure 2, lay between our jump-off line in front of Landres-et-St. Georges and the objective line along the crest of the Côte de Meuse west of Barricourt. It is 6 kilometers (5 miles) wide, and has an area of 44 square kilometers. The topographic description of a small area is difficult enough, and particularly so when direct observation can not be made. The remarks on the convexity of valley walls and on the importance of gullies were due to observations around Cheppy, and are probably the most valuable part of the paper.

With good maps on the scale of 1:20,000, and opportunity to view the country from a balloon, descriptions of this type would be rather easy to prepare. They should be useful to infantry officers to explain the maps which are now commonly furnished to them with orders to attack. Later, the same description would furnish material to the Corps Press Officer for the daily description of the terrain which he furnishes to correspondents.

MEMORANDUM OF THE WATER COURSES AND VALLEYS OF THE ZONE OF ADVANCE OF THE 5TH ARMY CORPS

The zone of advance of the 5th Army Corps lies on the western slope of the Côte de Meuse. This striking geographical feature is a ridge which has a very steep eastern slope and a gentle western slope. It extends north as far as Verdun, and thence northwesterly, dying out in a series of low hills in the vicinity of La Chesne. The sinuous valley of the Meuse River breaks the continuity of the ridge east of the Corps Area, while the valley of la Bar River, extending from the lowlands near Buzancy north to Sedan, marks approximately its northern boundary.

The streams which drain the Côte de Meuse flow northeast and east to the Woevre Plain and Meuse River and southwest to the Aire River from a broad divide. The streams which flow northeasterly lie in sharp, steep-sided canyons and divide the eastern border of the Côte de Meuse into a series of ridges which extend like stubby fingers into the Woevre plain. The southwesterly streams are longer, have wider valleys and gentler gradients.

The divide between these two stream systems is usually flat, and from ½ to 1 kilometer wide, and generally wooded. South of Bantheville the divide lies west of the crest of the ridge; north of this point the stream divide swings northwestward and corresponds to the crest of the Côte de Meuse. In a general view only the gentle westward slope of the plateau is visible. The stream valleys are concealed. The drainage divide is only a part of the general plateau surface which slopes gently west and southwest. Occasional knobs, such as the Côte Dame Marie and the Garenne de Moulin, rise above the general level. Such knobs are usually located on the divide. Because of their steep and wooded slopes the enemy uses these knobs as strong points. They have also high value as sites for observation posts. Military operations along the wooded divide are difficult, but the history of fighting in the Bois de Gesnes, Bois de Romagne, and Bois de Chauvignon show that the divide once attained commands the lateral valleys. North of the present line the divide is marked by Bois d'Andevanne, le Fey Bois, and Bois de la Folie.

Since the eastern boundary of the Corps Area runs along the drainage divide as far as le Fey Bois, the right division will have no running water to cross except on its extreme left wing. The upper parts of Ruisseau St. Georges, and Ruisseau de

l'Agron are very small streams, and present no obstacles. The left division will cross both streams with its whole front. These streams are shallow brooks easily waded except in very wet weather. Like all the streams of the region, however, the brooks are lined with trees and bushes, and these furnish natural concealment to small bodies of men. North of Imecourt an unnamed stream flows diagonally across the field of action of the left division. It is, however, no larger than those previously mentioned, and it should be possible to cross freely from one side to the other. The bushes and trees along its banks will furnish some cover in the valley, otherwise easily commanded by fire from an enemy stationed near Bayonville et Chennery.

The succession of stream valleys which one after another cross the Corps Area present much more serious obstacles than the streams which flow in them. A brief description is therefore given. There are three important valleys: (1) The valley of Ruisseau St. Georges; (2) Valley of Ruisseau de l'Agron; (3) Valley of the unnamed stream flowing from Bayonville et Chennery to Imecourt. Each of these valleys is about 1 kilometer wide. The slopes are gentle, cleared and cultivated. The slope of the valley walls is, however, convex upward, *i.e.*, the upper part of the slope is gentle, the lower part steep. Thus it is necessary, in most cases, for an observer to come part way down the slope to see the bottom of the valley, and, vice versa, an observer in the bottom of the valley can rarely see the crest. The importance of this dead ground is obvious.

In general, the tributary valleys are mere crenulations on the valley walls, and consequently of little value. In each of the three valleys there is, however, an important exception.

In St. Georges Valley, at the town of Landres-et-St. Georges, and extending due north for a kilometer, and thence to and beyond Ferme la Bergerie, is a deep ravine. In this ravine is an enemy narrow-gauge railway. Once the heights on either side are taken, this ravine affords ready communication, free of enemy observation, to the heights dominating the valley of Ruisseau de l'Agron.

From the valley of Ruisseau de l'Agron the ravine of Farbo Ruisseau extends about 1½ km. north of Landreville. It is approximately parallel to the valley from Imecourt to Bayonville et Chennery; consequently, from the region of Imecourt and Landreville to the north our left division will be progressing with the grain of the country instead of against it. This sudden change in terrain will have proportionate effect.

The valley of the unnamed stream from Imecourt to Bayon-

ville is not essentially unlike the others. North of Bayonville et Chennery, however, it forks almost at right angles. A third ravine gives the head of this valley a fanlike arrangement of ravines. Once Bayonville is held these ravines offer excellent lines of approach against the heights from Barricot Bois to Bois de la Folie.

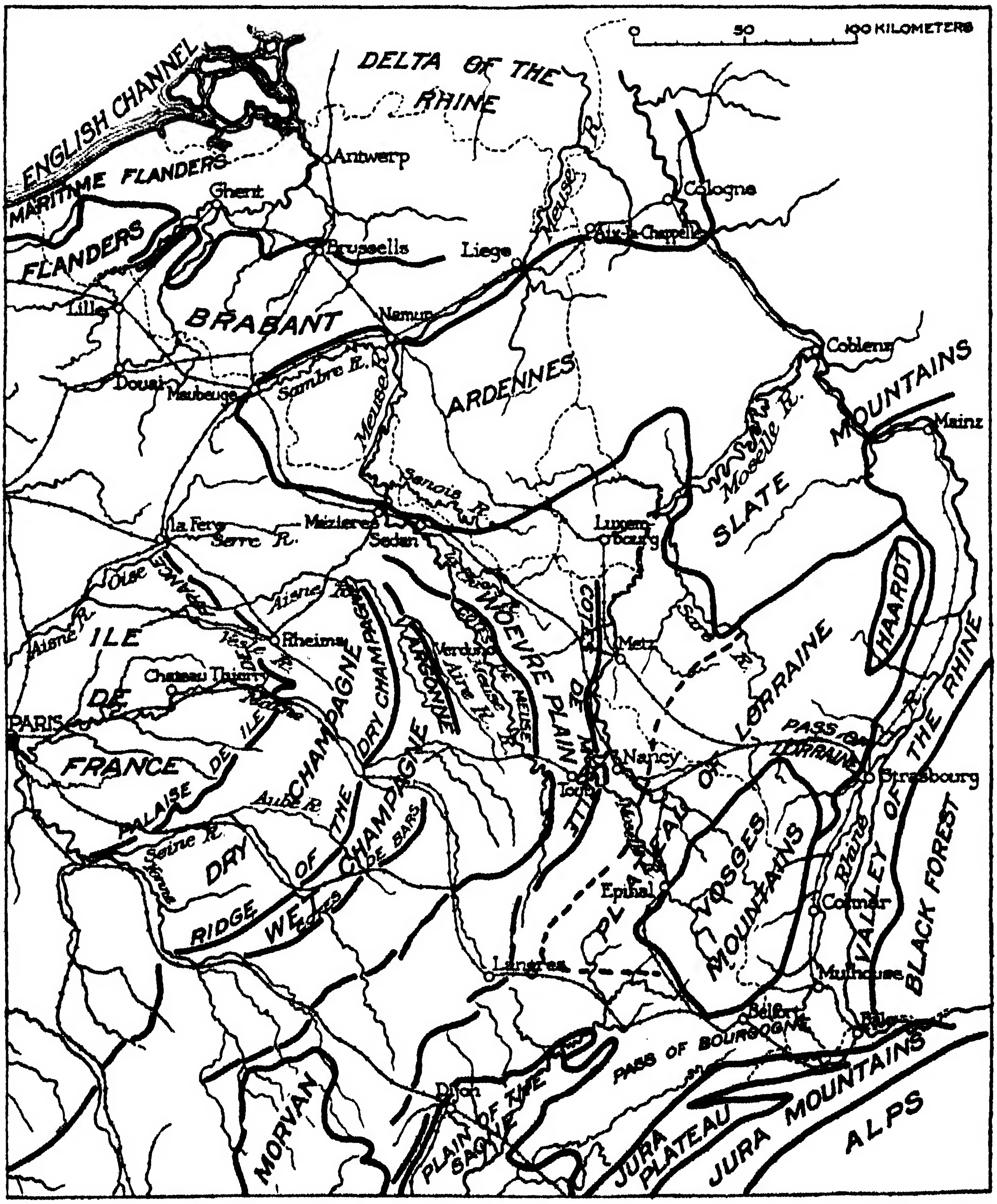


FIG. 3. MAP OF THE MAIN RAILROADS AND PHYSIOGRAPHIC PROVINCES OF THE EASTERN FRONTIER OF FRANCE.

While in general the valley walls are smooth, and the valley bottoms are grassy meadows, there are a few narrow, steep-banked gullies. These gullies are from 5 to 15 feet deep, from 10 to 50 feet broad, and from $1/16$ to $3/4$ of a mile long. The

gullies seem to be recent in origin and due to concentration of flood waters since the clearing of the original forests. Each gully forms a natural trench with a natural camouflage of overarching bushes. The Germans use the gullies very cleverly for machine-gun positions, artillery positions and dugouts.

Map of the Physiographic Province of Northeastern France

About the middle of October the need of a map of northeastern France on a sufficiently small scale to be studied readily when held in the hand seemed plain though no maps of this type were furnished us. Our officers were continually handicapped by the necessity of handling large maps crammed with detail of little significance for the major problems. Captain (then First Lieutenant) Thomas H. Thomas, Officer in charge of Enemy Order of Battle, requested Lieutenant Holmes to have me compile a map to show the main railway lines of northeastern France. This opportunity enabled me to make such a map and one that could also be used to show the location of the physiographic provinces. The map was made by tracing and piecing together the small maps on the scale: 1:2,000,000 which appear in the Atlas Classique de France, by Schader & Galleuedec to which reference has already been made.

The completion of this map was delayed by my being assigned to the advance echelon at Cheppy, but the lithograph was completed by November 5. While the lithographers were at work a tracing of the physiographic provinces was made in blue hectograph ink. By use of the jelly roll the boundaries of the provinces were over-printed on the black lithograph in blue. This map excited much interest among our officers, and with and without the overprint it would have been very useful if operations had continued. It is reproduced in Figure 3, redrawn so as to be reproduced in one color and to eliminate some of the crudities of the original.

Value of the Work.

To estimate the value of Intelligence Work is difficult enough, and one can not be sure that any of these efforts had any value in the final result. However, the following quotation from Colonel Russell's report on the work of G–2, 5th Army Corps in the Meuse-Argonne is typical of his generous attitude:

> Among the draughtsmen of the Topographical Section was an expert geologist, who prepared an excellent study on "The Military Topography of the Argonne Region," "A Memorandum on the Water Courses and Valleys of the Zone of Advance of the 5th Army Corps," and a "Map

of the Physiographic Provinces of the Eastern Frontier of France." This work is normally beyond the scope undertaken by the Corps, and falls more naturally under Army activities, but Private Kirk Bryan (now Second-Lieutenant Engineers) prepared the studies on his own initiative, and they were too good not to be published.[8]

Part II. Suggestions for the Use of Physiography in the Army

Reports on Topography

In the foregoing sections, the use in military operations of studies of topography has been illustrated. Many other examples could doubtless be culled from the Intelligence reports of the various armies engaged in the Great War. Future studies of this kind will fall naturally into two groups: (1) studies of large areas; (2) studies of areas of moderate or small size. Studies of large areas will partake of the general character of the report on the Argonne Region and the map of the physiographic provinces of northeastern France. Work of this type will be undertaken as a basis for strategical plans and study, or for the general information of officers and troops. It is naturally a duty of the staff of an army or the higher command in a campaign involving more than one army. Moderate-sized areas will ordinarily be involved in the sphere of an army corps. The problems will be tactical, but the occasions for making the studies may be of different sorts. In the example given in preceding pages the object was to describe a small area for the information of troops immediately before an attack. It is conceivable, however, that a detailed description illustrated by block diagrams and profiles would be of great value in solving the tactical problems of the slow reduction of an enemy position. The complicated topography of the Côte Dame Marie and adjacent hills would have furnished a fit subject for such a study.

Genetic Study of Land Forms

It is well recognized among physiographers and geographers that a complete understanding of land forms, that is, topography, can only be gained and remembered by a study of the origin of these forms. This study of genesis has led to the conception of the earth's surface as a series of repeating patterns, the patterns being identical where like rocks have been sub-

[8] Russell, Geo. M., Colonel G. S., Assistant Chief of Staff, G–2, Report of the Second Section, G. S., 5th Army Corps, U. S., Jan. 27, 1919. Intelligence Section, 5th Corps in Meuse-Argonne Operations, Ms. p. 22.

jected to like conditions for equal times. Davis has summed up this condition in the dictum: Form equals structure plus process plus stage. As a result of the application of this dictum, the trained physiographer has a classification of hills, of valleys, of shore lines, etc., imperfect enough, but sufficiently exact so that a single term calls up to his mind solid objects very complex in form, and frequently difficult to describe as individual or abstract units.

Just as he has classified single land forms, so he has divided the earth's surface into tracts of country having similar land forms or similar diversification of topography. By means of these divisions he has simplified the task of learning the characteristics of the topography of whole continents. Thus, both systematic physiography and descriptive physiography are a necessary part of the training of a professional soldier, for concise statements defining the character of the terrain form the basis for tactics and strategy. To the thoroughly trained officer operating in a region with which he is familiar, knowledge of the terrain comes easily, as part of his daily observation and map study. He hardly realizes what a large rôle it plays as a background for his thought, nor the difficulty which other men may have in acquiring the same knowledge. Thus the French had no geological officers, for a knowledge of French geology and physiography is a part of the training of every educated Frenchman, and many of their permanent officers are amateur geologists.

The American Expeditionary Force, operating in a strange country, with officers the bulk of whom were but recently civilians, needed an adequate system to supply information regarding topography, geography and geology. For engineer units, the geologic section of the Chief Engineer's Office, G. H. Q., under Lieutenant Colonel Alfred H. Brooks, supplied geologic information in a satisfactory manner. There was, however, no organized attempt to supply the army with predigested topographic information.

Peace-time Conditions

In peace time the courses in physiography in military colleges should be strengthened, and colleges which maintain a Reserve Officers' Training Corps, should make courses in physiography compulsory for men enlisted in the Corps The courses should be complete and thorough, but no special military flavor is necessary. An American army officer, even with his frequent transfers, can not be personally familiar with so great a country

as the United States. Our possessions are also quite extensive and widely scattered. The regular army officer, on transfer to a new post, should be able to quickly search out, read and understand the available physiographic literature. He will thus most rapidly obtain that grasp of the terrain which will make his military knowledge and ability most useful.

The physiographic studies of large areas here advocated will become a part of the Monographs of Military Intelligence now published by the General Staff of the Army. The studies of smaller areas will be useful in the preparation of the Zone Handbooks of the same organization.

Use of Physiographic Material in Training Periods

Knowledge along physiographic lines is rapidly being advanced. No artificial stimulus seems necessary, but areas of particular military value might be put on a preferred list by State and National Surveys. At the present time fuller knowledge of the Mexican border would be of great potential value. Prior to the outbreak of war, however, special pamphlets giving a brief but comprehensive description of the theater or probable theaters of war should be prepared from the constantly increasing body of physiographic literature. These pamphlets might well be prepared, at the request of the Army, by the United States Geological Survey. Such a plan was already on foot at the close of the war and abandoned because of the armistice. These pamphlets should be distributed to all officers and officer candidates. Judging by the popularity of D. W. Johnson's "Topography and Strategy of the War," such pamphlets would be eagerly read and studied.

As a stimulus to map reading and to the acquirements of the art of observation, short descriptions of cantonment and billeting areas are useful. These should contain simplified physiographic and geographic descriptions with accounts of local points of historic and scenic interest. They should be longer, but similar in character to the descriptions which were prepared during the late war, and printed on the backs of topographic maps of cantonment areas. Since these pamphlets would be simple compilations of existing material, and of no special value to the enemy, they should be available to all ranks.

Personnel in Active Operations

At the outbreak of war, a suitable group of geologists should be chosen for duty with the Army. It is obvious that they

should not be too old, nor more valuable at home because of expert knowledge of war minerals. The ranking officers should, however, be men of maturity and sound judgment. All the geologists in the Army should be responsible to a single officer for the technical side of their work. The geologic work done to determine suitable locations for dugouts may be equally valuable in solving a question in water supply; also, the same books and maps are necessary in preparing physiographic studies as in locating well drained sites for camps and hospitals.

Geologists with special aptitude for physiographic work while remaining under technical supervision of the Chief Geologist should be detailed to the Intelligence Section. To these officers will fall the work of preparing studies of the topography for the information of officers responsible for operations. These studies will then fall in line with other studies prepared in the Intelligence Section (G-2), and can be circulated in the same fashion.

Duties of Officers Assigned to Intelligence Section

The studies instituted by geological officers with G-2 will be of two types: (1) confidential reports to the higher command in advance of decisions, (2) general reports to lower units after decision.

Confidential reports will be dependent, for their effectiveness on the good judgment of the geologist, and he should be specially selected and of the highest caliber. He must have and retain the confidence of responsible officers, and for the best results he should have relatively high rank and should be assigned to, or be a member of the General Staff.

After decisions have been made as to the field of operations, or for offensives in large areas, reports should be sent out from Army Headquarters describing the topography, geology and other features of the terrain. These reports should be of a general character, somewhat similar to the "Military topography of the Argonne Region," but longer and with more detail. These reports should be illustrated by special maps, diagrams, and photographs, and so designed as to excite interest and to stimulate thought and observation in officers of the lower echelons. These general reports may well be followed later by special memoranda commenting on certain features of the landscape which experience has shown to have particular military importance. The illustrations for the reports will tax the ingenuity of their author, since the material should be presented in as graphic and pictorial a manner as possible.

When an offensive involving a corps or army front has been decided on, the geological officers should prepare special reports for each corps on the topography of the zone of advance. These reports should be circulated with orders to attack. They should be so written that they do not imply definite boundaries to the corps zone of advance, or define the objective, else by falling into the hands of the enemy early in the attack they give him useful knowledge. With this proviso they should be circulated down to platoon commanders. These men, in particular, should have their imagination stimulated, and visualization of the map made easy by a written description. Necessarily, they will have had less technical training than officers of higher rank, yet the platoon commanders must first penetrate into the new country. In the late war many platoon commanders went forward for five or six kilometers, with no map and no information but the order to follow a certain compass direction. A small-sized sketch map and a written description of the country are certainly not too much to give them.

The preparation of these descriptions will probably be the most difficult task of those outlined in this paper. The areas will be small. In many instances, the hills, valleys, and streams have no local names. The differences between adjacent hills may be very slight and difficult to describe. Also the audience addressed will contain men of all degrees of education with very diverse civilian occupations, and of many temperaments. All these men will be tired, worn with anxiety, restless from excitement, and many of them hungry. They will be compelled to read the statement under all conceivable conditions of discomfort and danger. It should then be short, simple, but vividly worded, and should drive home important points by repetition of simple phrases.

These descriptions for the attack should be rewritten for the Press Officers of each Corps. It is the duty of these officers to furnish daily to war correspondents a description of the country in which fighting occurs. They are usually newspaper men, and will quickly absorb and make popular the phrases which the geologist-physiographer applies to the topography. Such work has its reflex action, since an American army, from general to private, reads the daily communiqués and the accounts of war correspondents at every opportunity. If the topographic descriptions in these accounts are good then the whole army is educated, and official descriptions such as have been advocated will have proportionately greater effect.

Facilities for Geological Officers

The geological officers performing the functions outlined above will require a small working library. Through the Chief Geologist they will obtain geologic maps and reports prepared for engineering purposes. They should also have access to the maps printed and prepared by the Intelligence Section (G–2–C). They should have the complete confidence of the Intelligence Section of the unit to which they are attached, and should have the right to have special maps and diagrams prepared by this organization through which also their reports will be circulated.

Field work along the firing line will often be necessary, and the geologists should have frequent conferences with line officers of all grades. Admission to observation posts of all types should be granted them for the purpose of viewing the enemy territory. Occasional use of observation balloons and even aeroplanes may also be necessary.

GROWTH OF NEW YORK AND SUBURBS SINCE 1790

By JAMES L. BAHRET

STATISTICIAN, PUBLIC SERVICE COMMISSION, NEW YORK

THE federal government has recently finished its fourteenth census. This fact suggests a retrospect of New York's growth in population since the first federal census of 1790. In that year, the city limits embraced the entire island of Manhattan, although approximately only the area south of Canal Street was divided up into city blocks. All the rest of the island was occupied by farms with the exception of several straggling hamlets. In the course of years, as Westchester County began to be invaded with continuous rows of houses reaching out from the north bank of the Harlem River, slice after slice was split off and annexed to New York City. Finally, in 1898, with the formation of the so-called "Greater New York," the city limits were fixed as they are at present.

In order to eliminate the disturbing effect on population figures due to changes in the areas of the enumerated units, the figures in this article, for every year, have been computed, from the census reports, for the various areas as they existed at the last federal census, 1910. Thus allowance has been made for transfers of townships from county to county. The only exceptions are the several cases where a township has been split up between two counties or equivalent units. Changes in areas of units of the New York Metropolitan District subsequently to 1910 have been inconsiderable.

WHAT CONSTITUTES ECONOMIC NEW YORK AND THE METROPOLITAN DISTRICT

In the accompanying map, Economic or Industrial New York—including the Jersey portion of the great community encircling New York Bay—is bounded by the heavy continuous line, stretching in a rough half-circle from Jones' Beach, just east of Long Beach, to the Raritan River. On the east, it coincides with the eastern boundary of Nassau County. On the north and west it coincides with the outer boundaries of the cities and towns whose names are entered on the map inside the heavy boundary line. These are the limits fixed by the United

States Census Bureau for Industrial New York, which in this article I prefer to call Economic New York.

Besides the municipality of New York, the Economic metropolis embraces the entire counties of Nassau and Hudson, and parts of six others: Westchester, Bergen, Passaic, Essex, Union and Middlesex.

Outside New York City, the principal municipalities included in Economic New York, with their population according to the state census of 1915, are: Newark, 367,000; Jersey City, 271,000; Paterson, 125,000; Yonkers, 91,000; Elizabeth, 82,000; Hoboken, 68,000; Bayonne, 64,000; and Passaic city, 61,000. Thirteen additional municipalities had in 1915 over 20,000 inhabitants.

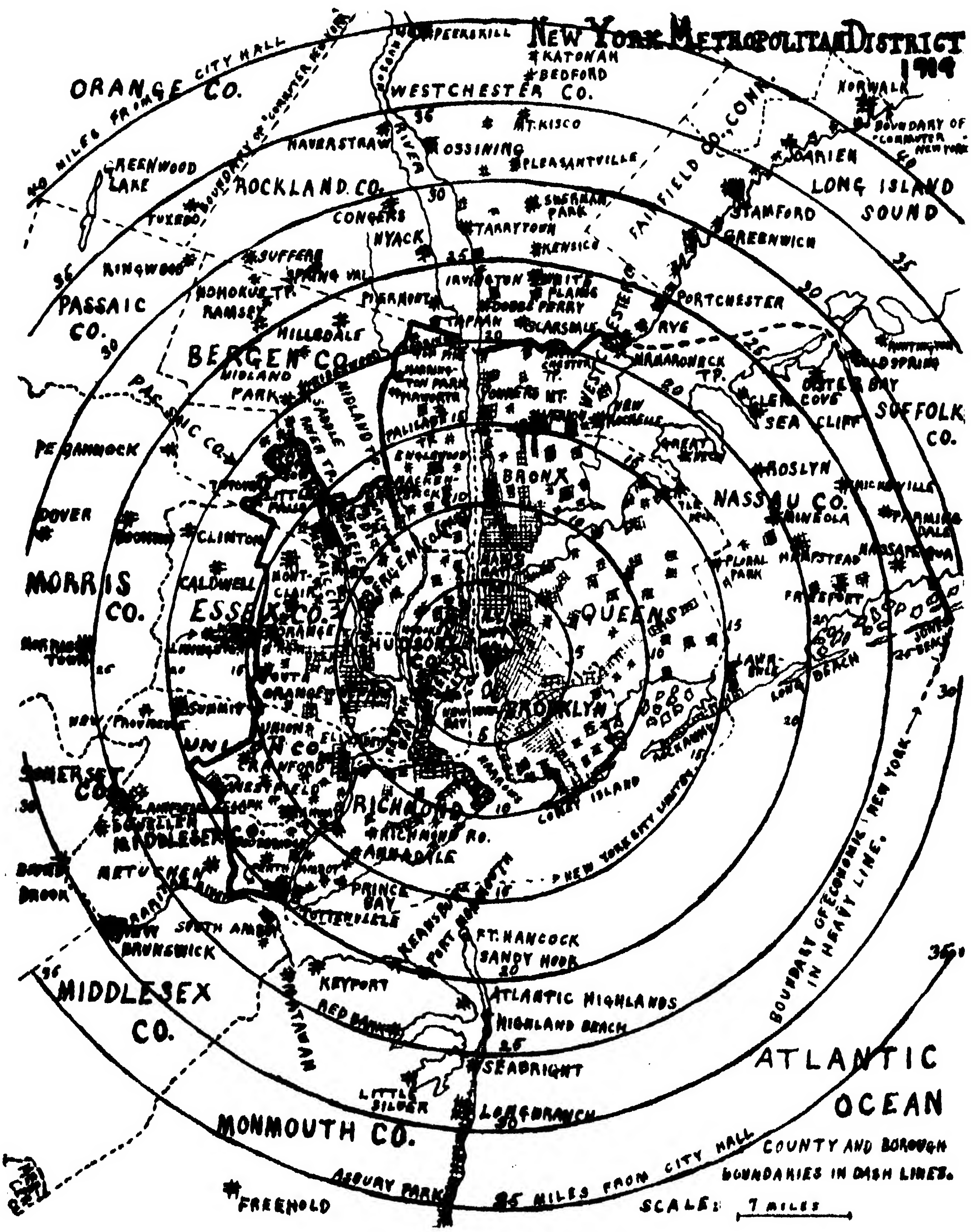
Some considerable places are just outside Economic New York, as fixed by the Census Bureau, as Plainfield, West Orange, Summit, and South Amboy. But the line had to be drawn somewhere.

But outside the limits of Economic New York tens of thousands of commuters reside. They form part of the day population of New York City. Therefore the first of the accompanying maps was drawn to show substantially all the territory within an hour by train of New York's business district. The territory shown on the map might be unified under the term "Commuter New York," or the "New York Metropolitan District."

Fairfield is the only county which lies partly outside the Metropolitan District, as delimited on the accompanying map, and represented in the following tables. Its towns are included only as far as Norwalk. But the entire counties of Westchester, Passaic, Morris, Somerset, Middlesex, and Monmouth are included, although their outer reaches are cut off on the map. Parts of Suffolk, Orange, and Mercer happen to be shown on the map, although they are here excluded from the Metropolitan District.

Some of the counties of the Metropolitan District were not in existence prior to the middle of the nineteenth century. But through our possessing census figures for the individual townships which were later combined to form the county, it is possible to arrive at the population of the present county areas decades before the organization of the counties. In the few cases where townships have at some time been split up between two counties, only approximate county figures are available for the earlier censuses. Moreover, for 1790, separate figures were never tabulated for all townships. It has therefore been necessary to divide the 1790 population of some of the counties that

lie partly within and partly without Economic New York, between the "Inner" and the "Outer" portions on the basis of the actual ratios of the "Inner" to the "Outer" population in 1800 (or even 1820, where earlier township figures are not available), taking into consideration, naturally, the actual rate



of growth of the county as a whole during the intercensal period. As none of the areas for which estimates must be made for 1790 had yet been invaded by Economic New York commuters, the hypothesis employed probably gives results not far from the unrecorded facts.

The 1915 population of southwest Fairfield has been esti-

mated on the basis of its increase from 1900 to 1910, Connecticut not having taken a state census.

Population of New York Metropolitan District

Division	1790	1820	1850	1880	1910	1915
New York City	49,401	152,056	696,115	1,911,698	4,766,883	5,047,221
Manhattan	33,131	123,706	515,547	1,164,673	2,331,542	2,137,747
Bronx	1,781	2,782	8,032	51,980	430,980	615,600
Brooklyn	4,495	11,187	138,882	599,495	1,634,351	1,798.513
Queens	6,159	8,246	18,593	56,559	284,041	396,727
Richmond	3,835	6,135	15,061	38,991	85,969	98,634
Outer Ring	37,520	56,758	142,354	578,947	1,707,685	1,929,183
In New York State	13,003	18,176	28,042	70,334	229,941	296,284
Inner Westchester	3,148	4,903	9,802	36,319	146,011	179,459
Nassau	9,855	13,273	18,240	34,015	83,930	116,825
In New Jersey	24,517	38,582	114,312	508,613	1,477,744	1,632,899
Hudson County	1,944	3,137	21,822	187,944	537,231	571,371
Inner Bergen	3,282	5,276	8,903	28,037	102,493	132,786
Inner Passaic	2,066	3,338	14,275	60,748	195,992	209,790
Inner Essex	7,718	12,422	50,178	180,233	488,120	534,842
Inner Union	5,834	9,385	12,128	42,744	107,053	124,209
Inner Middlesex	3,673	5,024	7,006	8,907	46,855	59,901
TOTAL, ECONOMIC NEW YORK	86,921	208,814	838,469	2,490,645	6,474,568	6,976,404
OUTSIDE COMMUTER DISTRICT	94,967	133,373	202,188	344,983	646,531	737,379
East of Hudson River	29,014	36,777	57,674	100,974	210,500	225,409
Outer Westchester	19,519	25,573	41,533	65,880	137,044	142,254
Southwest Fairfield	9,495	11,204	16,141	35,094	73,456	83,155
West of Hudson River	65,953	96,596	144,514	244,009	436,031	511,970
Outer Bergen	6,047	9,725	5,822	8,744	35,509	45,810
Outer Passaic			8,294	8,112	19,910	26,574
Outer Essex	1,915	3,076	6,036	9,696	24,766	31,482
Outer Union	1,580	2,572	5,608	12,827	33,144	43,113
Outer Middlesex	9,445	12,818	21,629	43,379	67,571	84,815
Rockland	3,329	8,837	16,962	27,690	46,873	46,903
Morris	16,216	21,368	30,158	50,861	74,704	81,514
Somerset	12,296	16,506	19,692	27,162	38,820	44,123
Monmouth	15,125	21,694	30,313	55,538	94,734	107,636
TOTAL, METROPOLITAN DISTRICT	181,888	342,187	1,040,657	2,835,628	7,121,099	7,713,783

By "Outer Ring" in the following tables is meant the territory outside the municipality of New York, but included by the Census Bureau in Economic New York. It includes nearly all the land area within about ten miles of the city's boundaries.

Manhattan Declining

Only two instances of decrease appear in the table. Manhattan declined from 1910 to 1915, and Outer Passaic from 1850 to 1880. The latter was not actual, being due to the slicing off

of portions of townships for annexation to Paterson. But Manhattan's decline was actual, although probably not on as large a scale as the 1915 census indicates. The state's canvass of the latter year was probably not thorough. Manhattan's population will continue to decrease uninterruptedly, because nearly all its building plots are already occupied by structures, and the tearing down of dwellings to make room for commercial and manufacturing buildings goes on rapidly. The corresponding "Central Area" of London—which happens to contain approximately the same number of square miles as Manhattan—has been steadily declining in resident population since 1861.

Relative Growth of Various Divisions of the Metropolitan District

The next table of percentages of increase shows to better advantage the relative growth of the various components of the Metropolitan District.

In the case of the five Jersey counties nearest New York City, it is necessary to enter, for the growth from 1790 to 1820, the actual rate for the combined area of the present counties. In 1790, that area formed only two counties, Bergen and Essex, and township figures are not available, or else the boundaries of the townships crossed present county lines. Later, Union split off from Essex, and Hudson from Bergen, while Passaic was formed from parts of Essex and Bergen. Likewise from 1820 to 1850, it is necessary to give a combined rate for Outer Bergen and Outer Passaic. In 1820 the latter formed part of the former, and through the subsequent splitting up of townships between the two, it was not possible to compute separate figures for the two areas for 1820.

New York's Population and the Erie Canal

There is a statistical law for population aggregations of considerable size: The larger the aggregation becomes, the slower the rate of growth. A glance at the table shows that this holds true for the municipality of New York except for the period, 1820 to 1850. This violation of the statistical law, and the tremendous advance in New York City's rate of growth from 1820 to 1850 over the preceding 30-year period, is due almost entirely to the opening of the Erie Canal in 1825. On account of mountain ridges, it was not possible to connect, by canal, any other Atlantic port of the United States with the great central prairie food reservoir of the country and the rich

Per Cent. Increase

Division	1790 to 1820	1820 to 1850	1850 to 1880	1880 to 1910	1910 to 1915
New York City	208	358	175	149	6
Manhattan	273	317	126	100	D 8
Bronx	56	189	547	729	43
Brooklyn	149	1,141	332	173	10
Queens	34	125	204	402	40
Richmond	60	145	159	120	15
Outer Ring	51	151	307	195	13
In New York State	40	54	151	227	29
Inner Westchester	56	100	271	302	23
Nassau	35	37	86	147	39
In New Jersey	57	196	345	191	10
Hudson County		596	761	186	6
Inner Bergen		69	215	266	30
Inner Passaic	61	328	326	223	7
Inner Essex		304	259	171	10
Inner Union		29	252	150	16
Inner Middlesex	36	39	27	426	28
TOTAL, ECONOMIC NEW YORK	140	302	197	160	8
OUTSIDE COMMUTER DISTRICT	40	52	71	87	14
East of Hudson River	27	57	75	108	7
Outer Westchester	31	62	59	108	4
Southwest Fairfield	18	44	117	109	13
West of Hudson River	46	50	69	79	17
Outer Bergen		45	50	306	29
Outer Passaic	61		D2	145	33
Outer Essex		96	61	155	27
Outer Union		118	129	158	30
Outer Middlesex	36	69	101	56	26
Rockland	165	92	63	69	00
Morris	32	41	69	47	9
Somerset	34	19	38	43	14
Monmouth	43	40	83	70	14
TOTAL, METROPOLITAN DISTRICT	88	204	172	151	8
New York State outside Metropolitan District	306	97	30	31	6
New Jersey outside Metropolitan District	57	63	64	65	11
United States, excluding outlying possessions	145	141	116	83	—

forests of the basin of the Great Lakes. Until 1865, the Erie Canal gave New York practically a monopoly of the wholesale supply trade and the tremendous export trade in food and forest-products of this great interior basin, embracing the American half of the valley of the Great Lakes, and particularly the upper half of the Mississippi valley.

New Yorkers should not begrudge any tax burdens due to the Erie Canal. It has already contributed billions of wealth to New Yorkers——those living outside the city as well as within —and made the city's population to-day double what it would have been if the canal had never been built. The canal will contribute billions more of money to New Yorkers, and continue

to boost tremendously New York's growth in population, if the federal government can be persuaded to cease imposing freight charges upon the canal such as cripple its inherent power to draw traffic from the railroads.

Economic New York and the entire Metropolitan District do not conform to the statistical law mentioned even to the extent that the municipality does because of the effect of the city's surging population spilling over into the neighboring areas outside the city limits.

Rate Wars and New York's Growth

The decline in New York's rate of growth is far more pronounced from 1850 to 1880 than for the succeeding 30-year period. This is because unified trunk railroads over the Appalachians from the middle west to the Atlantic ports date only from 1865. Immediately the bitterest rate wars broke out between these trunk lines, and lasted almost continuously until 1880. These rate wars largely nullified New York's unique position among the Atlantic ports of the United States in possessing an all-water route and a water-level rail route to the middle west. Trunk railroads tributary to Philadelphia, Baltimore, Norfolk and Newport News, though having to climb over several mountain ridges—as compared with no mountain ridges for New York *via* the gaps in these ridges through which the Hudson and the Mohawk rivers pass—offered to carry export freight from the middle west at less than cost in order to build up their own traffic, and knock in the head the natural flow of rail-borne, as well as water-borne, commerce to New York. For Nature had favored in every way the location of our city to become the site of the metropolis and commercial capital of the Western Continent, and ultimately of the world.

As a consequence of these rate wars depriving New York of a large share of the trade that would naturally flow to it, a damper was put on New York's growth in population from 1850 to 1880, notwithstanding the vastly increased foreign immigration during that period.

Effect of Freight Differentials

And when the rate wars finally ceased, in came the Interstate Commerce Commission, and established freight rates in favor of the four ports named, so that they could fatten—grow in trade and consequently in population—at the expense of *Little Old New York.*

Although the actual cost of transporting a carload of grain from St. Louis or Chicago to one of the ports named is greater than to New York, the Interstate Commerce Commission, for more than a quarter of a century, has granted these four ports a lower rate than New York's! New York's rail distance from Chicago or St. Louis is close to one hundred miles greater than in the case of these four ports, but the route is practically all level, and even largely down grade, as compared with close to a hundred miles of heavy ascending grades for its four rivals. The time of transit to New York is less than to its rival ports.

New York's population growth has truly been phenomenal. But it would have been even greater if it were not for the differentials established by the Commission named. The federal government has in general manifested antagonism to its metropolis and greatest port. It has resorted to a number of artificial expedients to nullify New York's unique natural advantages, decentralize the nation's export trade, which Nature ordained should be concentrated at the mouth of the Hudson, and build up New York's rival ports at the latter's expense.

Richmond's Lag

The percentage table shows that Manhattan and Brooklyn's rates of growth have continuously decreased since 1850, while those of the Bronx and Queens continuously increased from 1790 to 1910. Richmond is the only borough which has, without exception up to 1910, increased at a rate below that for the city as a whole. (It should be remembered that the present divisions of the Metropolitan District have been carried back to 1790.) Richmond's rate for the past century in its entirety has been much below that of the other boroughs, as well as of the Jersey divisions of Economic New York. While Richmond surpassed the Bronx in population up until after the middle of the nineteenth century, in 1915 it contained less than one sixth as many inhabitants. Though much nearer New York's business center in miles, its insular position and lack of rapid transit have caused it to fall hopelessly behind.

Effects of Invention of Steamboat

The most notable increase in the percentage table, that of Brooklyn from 1820 to 1850 (1,141 per cent.) was due to the displacement of rowing and horse-treadmill ferries by steam ferries about 1810. New York business men refused to make their homes across the narrow East River in Brooklyn until the

advent of the steam ferry set at nought the rapid current of that tidal stream.

Effects of Rapid Transit

Two of the other most remarkable increases are those of the Bronx from 1850 to 1880 (547 per cent.), due to its invasion by the east-side elevated railway, and from 1880 to 1910 (729 per cent.), due to the opening of the first elevated extensions of the Interborough subway.

New York City (present area) increased much more rapidly than its Outer Ring up to 1850. Since that year this relation has been reversed, owing primarily to vast improvement in facilities for getting to the west of the Hudson, first steam ferries displacing treadmill and sailboat ferries, and later tunnels in large part displacing steam ferries. A factor almost equally important was the later vast improvement in train service, which lured many New York business men to establish their residences in the Outer Ring.

Up to 1910, Economic New York increased far more rapidly than the Outside Commuter District. Since that year, conditions have been for the first time reversed.

New York state and New Jersey outside the Metropolitan District have increased far less rapidly than the District.

Three States Benefit by the Port of New York

The percentages of the population of the Metropolitan District residing in the different states have been as follows:

Economic New York

	1790	1820	1850	1880	1910	1915
New York State	72	82	86	80	77	77
New Jersey	28	18	14	20	23	23

Entire Metropolitan District

	1790	1820	1850	1880	1910	1915
New York State	47	60	75	73	73	72
New Jersey	48	37	23	26	26	27
Connecticut	5	3	2	1	1	1

New Jersey's proportion steadily declined until 1850. Since that date it has been on the increase. As already indicated, the reason for the change in trend is the vast improvement since 1850 in facilities for getting west of the Hudson.

New York's Rival Metropolises

There is next presented the population growth of all other metropolises of the world having more than 1,500,900 inhabitants in 1910. But Petrograd is omitted because its published population has rarely been the result of an actual count. During the entire existence of the city, only two or three censuses have been taken. But particularly, its population has dwindled to less than a million as a result of the World War.

For Tokio prior to 1880, only estimates by Japanese statisticians are available. After 1850, Tokio became semi-depopulated because it ceased to be Japan's capital. When restored as the capital, it more than recovered its lost ground.

In cases where the censuses of foreign metropolises were taken in different years from those of the United States census, the population figures have been synchronized on the assumption of a uniform annual increase during the intercensal period.

Population of New York's Rival Metropolises

City	1790	1820	1850	1880	1910
Greater London	884,000	1,569,000	2,636,000	4,679,000	7,184,000
Paris	448,000	749,000	1,350,000	2,213,000	2,867,000
Chicago	....	....	30,000	503,000	2,185,000
Berlin	151,000	226,000	454,000	1,122,000	2,071,000
Tokyo	1,000,000	1,500,000	1,500,000	858,000	2,062,000
Vienna	219,000	260,000	425,000	1,137,000	2,031,000
Philadelphia	29,000	64,000	409,000	847,000	1,549,000

Per Cent. Increase

	1790 to 1820	1820 to 1850	1850 to 1880	1880 to 1910
Greater London	77	68	78	54
Paris	67	80	64	30
Chicago	..	..	1,576	334
Berlin	50	101	147	85
Tokyo	50	00	D 43	140
Vienna	19	63	168	79
Philadelphia	121	539	107	83

Chicago and New York

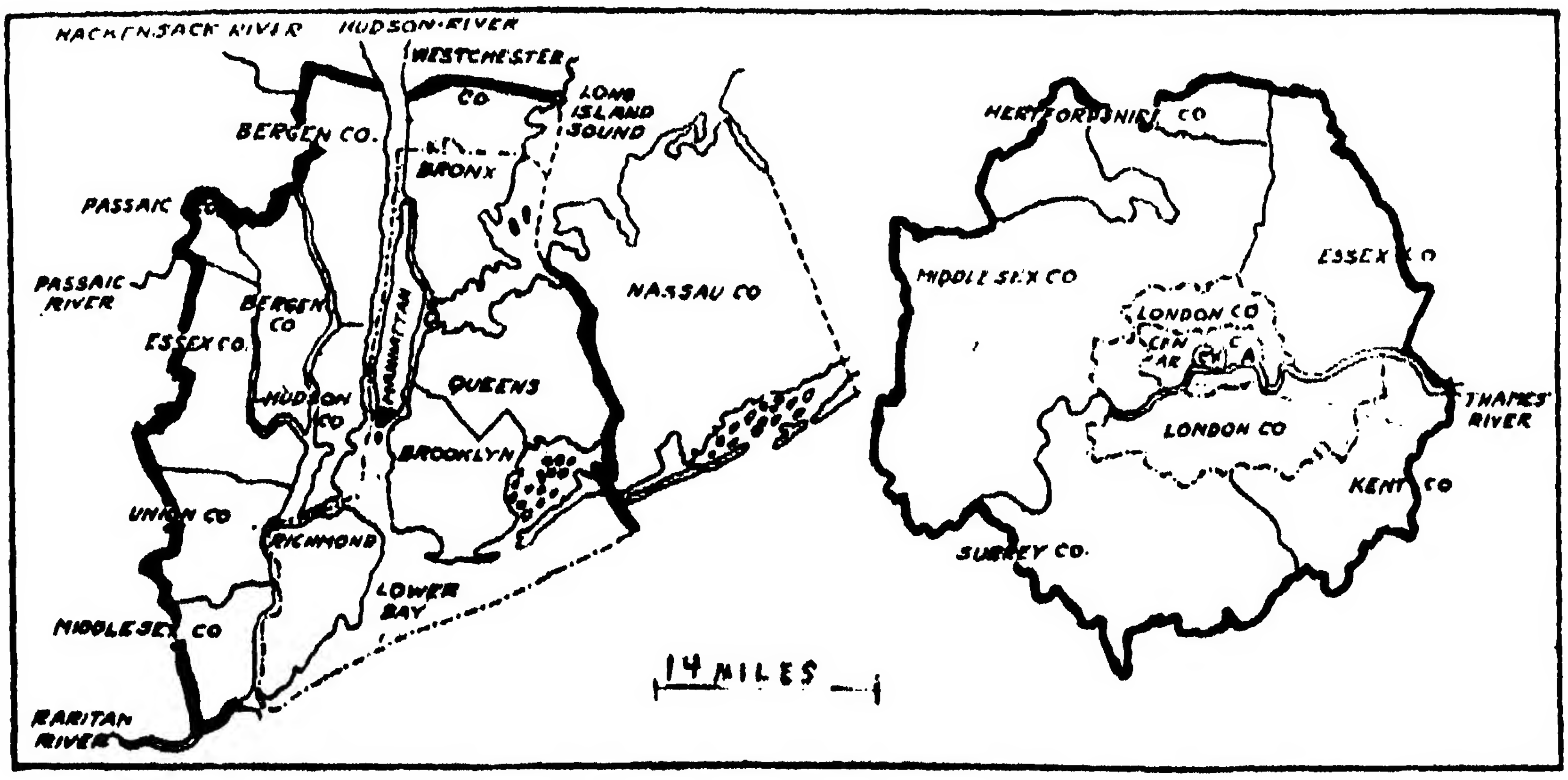
The only metropolis of the world that has threatened to overtake New York is Chicago. Her phenomenal increase from 1850 to 1900 truly scared the lovers and partisans of *Little Old New York*. We did not want ultimately to be compelled "to go way back and sit down." We were on the anxious seat until the 1910 census returns were published. These showed an increase

for *Economic Chicago* for the decade just ended of 33 per cent., as compared with *Economic New York's* 41. Hurrah again for *Little Old New York!* She can't be beaten in the long run. By 1910, Chicago had shot her arrow and fallen short of the mark, so ardently striven for by her business men, of the premiership among not only America's but the world's cities.

NEW YORK AND LONDON

But a still greater triumph fell to *Little Old New York* only three years ago. And few New Yorkers have as yet heard of it. They have been ignorant of the fact that since 1917 they have been living not only in the largest city in the world, but the largest this planet has ever seen.

There has been much dispute in various publications as to whether New York or London is to-day the largest population aggregation in the world. To settle the question definitely, the writer has taken the trouble to compute from the census returns for the two metropolises their population living on approximately equal land areas, the only fair basis for a comparison. Political boundaries form an entirely artificial basis.



Economic New York: New York City embracing the boroughs of Manhattan, The Bronx, Brooklyn, Queens and Richmond; Outer Ring embracing Hudson County entire, and parts of Westchester, Bergen, Passaic, Essex, Union and Middlesex. Manhattan south of Fulton Street (shaded) corresponds to London "city" (Cy.). The Census Bureau includes Nassau, but this county is here omitted in order to make the two areas approximately equal.

Metropolitan Police District of London: Embracing the entire counties of London and Middlesex and parts of Hertfordshire, Essex, Surrey and Kent.

Moreover, it is not generally known that the population of London, as usually published, is not for any political entity. It is the combined population of numerous cities, boroughs, and

towns lying within a radius of eighteen miles—roughly speaking—of the center of London Bridge. Just as Economic New York, as delimited by the federal Census Bureau, is an aggregation of cities, boroughs, and towns.

Some pseudo-statisticians, in their defense of London, have taken Economic London on both sides of the Thames to compare with only that portion of Economic New York which lies on one side of the Hudson!

London and its suburbs happen to have a unified police administration, just as Néw York did half a century ago, but soon abandoned. The population "of London" generally published is for its Metropolitan Police District. The correponding area for us Knickerbockers is Economic New York. But the limits established by the Census Bureau make Economic New York cover 271 more land square miles than does the Metropolitan Police District of London. In order to make the areas approximately equal, I have omitted Nassau County entire from the comparison, because it is the least densely populated large section of Economic New York. This omission gives London the advantage over New York by 3 land square miles. Further, Economic New York, exclusive of Nassau, contains to-day 95 square miles of uninhabitable salt marsh, while London contains practically no uninhabitable land. This gives London an additional considerable advantage in the comparison—at least ten per cent.

I have computed from the census reports for the two areas described the records, since the beginning of the nineteenth century, of the two contestants in the race for the premiership among the cities of the world.

GROWTH OF THE METROPOLITAN POLICE DISTRICT OF LONDON
(693 LAND SQ. MI.)

Census Year	County of London		Outer Ring		Total, Metropolitan Police District	
	Population	Per Cent. Inc.	Population	Per Cent. Inc.	Population	Per Cent. Inc.
1801	959,310	—	155,334	—	1,114,644	—
1811	1,139,355	18.4	184,544	18.4	1,323,899	18.4
1821	1,379,543	21.1	216,808	17.5	1,596,351	20.6
1831	1,655,582	20.0	247,990	14.4	1,903,572	19.2
1841	1,949,277	17.7	286,067	15.4	2,235,344	17.4
1851	2,363,341	21.6	317,594	11.2	2,680,935	20.3
1861	2,808,494	18.8	414,226	30.4	3,222,720	20.2
1871	3,261,396	16.2	624,245	50.8	3,885,641	20.6
1881	3,830,297	17.4	936,364	50.0	4,766,661	22.7
1891	4,227,954	10.4	1,405,852	50.1	5,633,806	18.2
1901	4,536,267	7.3	2,045,135	45.5	6,581,402	16.8
1911	4,521,685	D0.3	2,729,673	33.5	7,251,358	10.2

On the basis of the annual increase during the latest intercensal period, I have computed the following estimates:

GROWTH OF ECONOMIC NEW YORK (EXCL. OF NASSAU) (690 LAND SQ. MI.)

Census	Present Limits of New York City		Outer Ring (Excl. Nassau)		Total Economic New York (Excl. Nassau)	
	Population	Per Cent. Inc.	Population	Per Cent. Inc.	Population	Per Cent. Inc.
1800	79,216	—	—	—	—	—
1810	119,734	51.1	—	—	—	—
1820	152,056	27.0	43,485	—	195,541	—
1830	242,278	59.3	56,227	29.3	298,505	52.7
1840	391,114	61.4	78.451	39.5	469,565	57.3
1850	696,115	78.0	124,114	58.2	820,229	74.7
1860	1,174,779	68.8	241,632	94.7	1,416,411	72.7
1870	1,478,103	25.8	396,633	64.1	1,874,736	32.4
1880	1,911,698	29.3	544,932	37.4	2,456,630	31.0
1890	2,507,414	31.2	780,089	43.2	3,287,503	33.8
1900	3,437,202	37.1	1,115,154	43.0	4,552,356	38.5
1910	4,766,883	38.7	1,623,755	45.6	6,390,638	40.4

Year	County of London	Outer Ring	Total, London Metropolitan Police District
1915	4,515,853	3,003,489	7,519,342
1916	4,514,395	3,071,943	7,586,338
1917	4,512,937	3,140,397	7,653,334
1918	4,511,479	3,208,851	7,720,330
1919	4,510,021	3,277,305	7,787,326
1920	4,508,563	3,345,759	7,854,322

Year	New York City	Outer Ring (Excl. Nassau)	Total, Economic New York (Excl. Nassau)
1915	5,431,723	1,878,055	7,309,778
1916	5,564,691	1,928,915	7,493,606
1917	5,697,659	1,979,775	7,677,434
1918	5,830,627	2,030,635	7,861,262
1919	5,963,595	2,081,495	8,045,090
1920	6,096,563	2,132,355	8,228,918

There is hardly room for the slightest doubt that New York, at the latest in 1920, has overtaken London, on the basis of equal land areas. Both cities were hard hit by the war, and thus the actual population increase of both, subsequently to its outbreak, will probably be found, when the returns of the forthcoming censuses are tabulated, to lag considerably behind what would be expected on the basis of the growth during the first decade of the twentieth century. But London was immeasurably harder hit by the war than was New York, and her growth in population has almost certainly been retarded the more.

Shall the Metropolitan District enter the Union as a Separate State?

This winter two bills have been introduced in the state legislature having as their object to set off New York City, together with several of the near-by counties of the state, as a separate member of the federal Union. If the metropolis and suburbs should ever enter the Union as a separate state, it should include, for both economic and political reasons, the commuter areas of New Jersey and Connecticut, as well as those of New York state. Particularly the development of port facilities lags because of the divided state jurisdiction. But this great defect will probably be remedied in a few years by the recently organized New York-New Jersey Port and Harbor Development Commission.

If the Metropolitan District, as delimited in this article, should become a separate state, its present New York state and New Jersey inhabitants, respectively, would no longer be burdened with paying the vast bulk of the state taxes of both commonwealths. But just because Economic New York is compelled to play "Lady Bountiful" to the outside areas of the two states, the latter's representatives in the state legislatures would never consent to a separation. On the other hand, the legislators from the Metropolitan District might be able ultimately to outvote the more or less rural Solons. In 1915, 57 per cent. of New York state's population resided in the Metropolitan District, and 74 per cent. of New Jersey's.

There is the sentimental reason that the splitting up of New York state would cause the latter to lose its primacy among the states in population, wealth and manufactures. New York has enjoyed the distinction of being the "Empire State," beginning with 1820.

If the Metropolitan District had been a separate state in 1910 (the year of the latest published federal census returns), it would have been exceeded in population by only one state, Pennsylvania, which then had 7,665,000 inhabitants, as compared with the Metropolitan District's 7,121,000. The remainder of New York state, with close to its present area, would have had a population of only 3,933,000, and ranked fourth among the states. The population of the remnant of New Jersey, although still including the vast bulk of its area, would have been only 670,000. Instead of eleventh rank among the states, New Jersey would have dropped to thirty-sixth.

But in 1929 the new state of "South New York" (as it would

be logically named, rather than "Manhattan" or "Greater New York," as proposed in the two bills before the legislature) would itself become the Empire State, since its estimated population, on the basis of growth from 1880 to 1910, would then be 9,838,000, as compared with Pennsylvania's 9,812,000.

But there are also material objections to the Metropolitan District's becoming a separate state. Things that happen upstate, such as the building of canals, railways, aqueducts, automobile roads, the regulation of dairy farms, etc., possess a vital interest for Gothamites, and have a marked bearing on the latter's health and happiness and chase for the "almighty dollar." It is very desirable that Gothamites retain their "say," and particularly their votes, in the transactions in Albany's legislative halls.

EDUCATION AND LEARNING IN AMERICA

By Professor ARTHUR GORDON WEBSTER

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IT is well known that we in the United States spend more upon education than any other country. What do we get for it? Are the returns in any way commensurate with the enormous sums expended? Does the number of institutions calling themselves colleges and universities to the neighborhood of perhaps 400 insure us and the community that it has the highest standards of learning or even appreciates it? I think there is no doubt that the answer to this question will be in the negative. We have been accustomed to flatter ourselves that the common schools are an American invention. We have no peasants in this country and we think that the average of education and intelligence is very high. And yet we find as a result of the psychological tests made upon about three million men in our Army that the average mental age of the soldier was about 13½ years. The officers were very good, it is true, but were chosen to a large degree from persons who had had the advantage of a college education. To that extent it is creditable to the colleges. But we have still to examine the question of the efficiency of the work of the colleges.

Last summer, while on a mission to France, largely educational in character, I was frequently at the Sorbonne. I found in passing through the great court of the new Sorbonne one day that it was full of young persons of the two sexes, and to my question, "Qui sont ces bébés?" the reply was made, "C'est pour le baccalauréat." There were young girls with curls down their back and I saw one boy with bare knees in the uniform of a boy scout. One must remember that the "baccalauréat" corresponds not merely to the finishing of the high school, but to perhaps the first two years of college, and you can imagine my astonishment. I said, "And will these boys be prepared for the Ecole Polytechnique [a school of the standard which I regard as the highest in the world] in four years?" "They will be ready in three years, monsieur." Let us remember that the Polytechnique is the school open to intending officers who have passed an extremely drastic examination for entrance. A friend of mine, Général Ferrié, who is in command of all the

French army telegraphs, told me that in the year he was admitted, out of 1,200 candidates 200 were admitted. Ask yourself whether there is any school in the United States of which merely to be a member is a distinguished honor, or which imposes for its membership any such qualification, and I have no doubt as to the answer.

In a recent newspaper President Eliot is quoted as attacking West Point. And the paper the next day says that it is proposed that a resolution be introduced into Congress to examine the curriculum. It is not the curriculum at West Point that needs examination. It is something far deeper.

In an article written by a professor in last December's *Atlantic Monthly* is an extremely good picture of a faculty meeting and its futility. Everybody is bored. No one can make a decision. Nothing is accomplished. Everybody goes away disgusted. I have seen such faculty meetings and I have seen such professors. Fortunately I do not belong to one. My thirty years have been thirty years of almost unmitigated pleasure and enjoyment, full of the joy of living, and marred only by th difficulty of making both ends meet and of finding the money either to finance my department or to get along with the small appropriations that have been available. But sweet are the uses of adversity (and university). I have learned to do it.

A few months ago, at a meeting of the American Academy of Arts and Sciences in Boston, I was accosted by a friend, one of the most learned of the members of the Harvard faculty, with the exclamation, "Well, Webster, I suppose you are not ashamed of being a professor as I am." "No," said I, "I am proud of it. What is the matter?" He replied, "I sat all yesterday afternoon in a faculty meeting discussing whether the football team, which had accomplished very little in an intellectual way during the last few months, should be allowed to go to Pasadena to give a gladiatorial show, and we decided that it should not. What was my disgust to read in the morning paper that the team was going!" When I heard this statement I wrote an article commenting on it to the *Harvard Alumni Bulletin*, stating that I should withdraw the modest subscription that I had made toward the fifteen million dollar fund. I said that inasmuch as no self-respecting person would wish to be a professor at Harvard it would be unnecessary to have a fund to raise their salaries. The letter has as yet drawn forth no comment.

Some dozen years ago the Nobel Prize of about forty thousand dollars was awarded to Professor A. A. Michelson, the great physicist of the University of Chicago and my predecessor

where I am. His colleagues at that institution were so delighted that they prepared to honor him by giving a banquet to which scientists in all parts of the country were invited. I was much pleased to be included and should certainly have gone had limitations of time and money not prevented. Later on, the same prize came to Professor Theodore W. Richards, the distinguished chemist of Harvard. Meeting him one day, I said, "Richards, what did they do for you in Cambridge?" "Do for me?" said he, seeming to misunderstand the import of my question. "I had some very nice notes." "Do you mean," said I, "that they did nothing in public to show the appreciation of the honor which you had received?" "No," said he. Whether this is characteristic of the difference between the effete East and the hustling, wide-awake Middle West I do not know. I merely know that when the victorious football team referred to returned from Pasadena it was given a banquet to show the distinguished honor in which the citizens of the intellectual community of Boston and Harvard held it.

Such stories as these are but symptoms. They are straws to show which way the wind blows. They would be possible in no other country than the United States. To be sure, we are a democracy. We believe that all men are *created equal.* There may be some who believe that men stay equal and there may be some who wish them to stay equal. I am not one of that number. We do not wear silk buttons on our coats, nor do we as a rule attach letters to our names. We do not become privy counselors, "wirkliche" or other, and we eschew all apparent marks of distinction. Sometimes we form exclusive societies to which we select a supposedly learned élite. It is cruelly said by outsiders, and sometimes by insiders, that the chief purpose of getting into such societies is to keep others out. However, this I do not wish to discuss.

Now, what is the reason for this state of affairs? It is frequently said that it is because the country is new. How new is it? If I am not mistaken, the United States is the oldest republic in the world, with the exception of San Marino and Andorra. For considerably over a century we have had a large measure of political freedom and an unexampled degree of prosperity. Ever since the close of the Civil War, with rare exceptions, we have had such a degree of prosperity that it has been possible for almost everybody to have a college education, with the result that our educational institutions are full of the most mediocre intellects, persons who, in the words of our Atlantic professor, really ought to be plumbers or something of an even less intellectual status.

A college is looked upon, according to the statement of Professor Lightner Witmer, of the University of Pennsylvania, at a meeting of the American Philosophical Society, as a country club somewhat marred by attendance at recitations. Many of the colleges are no more than schools of a somewhat superior grade, and it is very noticeable that students and even professors coming from the South and West almost uniformly refer to the college as a school. And the phrase, "When will school open?" is most familiar.

The young man writing the prize essay on Harvard is frankly of the opinion that the so-called men at Harvard are treated like school boys, that facts are poured into them, that only their memory is made use of, that they are not taught to think and reason for themselves. The trouble again, in my opinion, is not with the institution, the system, the professors, but with the community. When going to college is looked upon as the culmination of a social career or preparation for the same, when the boy or girl can say, "I don't have to work; father will pay," it is a sign that something is wrong with the community. When the woman who comes in to do the washing asks the head of the family what her husband does and she says, "He is a minister," and the washerwoman says, "Oh, of course, I don't blame him; he has got to do something," as I heard told recently, it is very obvious that something is wrong.

In this country the only criterion of success is the amount of money that a person has made. Two years ago, having done a little profiteering, I bought a modest automobile. One day when I was taking a young lady, a friend of my daughter's, out to drive, I said to her. "People think much more of me now that I have an automobile." "Oh, yes, Dr. Webster," she responded. This was a graduate of one of our leading colleges for women, a very bright young woman indeed. And yet she immediately fell for my jocular remark.

How is it that boys and girls of fifteen and sixteen in France can pass the examinations for entrance at the Sorbonne? Are they brighter than our boys and girls? No. But they look upon education as a serious business. They look upon an educated man as a superior person. They consider the chief aim of man not to be the accumulation of a certain number of millions of francs, but the accomplishment of some creative task. In Paris it is not the fat profiteers riding about in limousines who attract the attention of the people. It is the members of the Institut, the great men of literature, science or art. Rightly does Paris call herself "la ville Lumière." France is still "la grande

nation." After a residence of any length of time in Paris, how tame seems life in the most attractive American city!

Last summer I visited by far the greater majority of the universities in France. I found the laboratories extremely meager, often in dark rooms, in old-fashioned buildings, the equipment very limited. But the spirit was splendid. Not in vain have fellowships for Americans going to French universities been founded, for there shall they find the true spirit of learning. At Nancy I was personally conducted by the rector over the university and adjacent parts of the city. He took me to the Lycée Henri Poincaré. Before the door stood a bronze statue of the great mathematician, probably the greatest intellect of the latter half of the nineteenth century. We passed into the court. "Ce n'est pas gai," said the director. No, it is not gay. The life of the French *lycéen* is slavery. Immured within the walls of the school, he is seldom let out except under the surveillance of an instructor. His life is extremely dreary. But they produce the goods. They do not go out for the team; they do not go out for the crew, or for the paper, or for the Glee Club, or for the theatrical profession. They go *in* for study and hard labor. They consider that learning is an end in itself and are not continually asking, "Why do I *hafter* do this?" The only thing that father wants is that his son shall become a distinguished man.

The trouble with education in the United States is with the community, with the fathers and mothers, who do not insist that their children shall do anything that requires exactitude, stick to it and not let up until they get it done. A few days ago my assistant in the laboratory was doing some computation with the calculating machine. I said to him, "It is a shame that you should be turning that coffee-mill; we ought to be able to get some boy from the college to do it." I inquired of the college professor of mathematics. He said, "There is not much use, because nobody now learns to do anything carefully and get an exact result." If a boy multiplies two by three and gets five, of course that is pretty near, it is the next number, but that is hardly what we want. Colleges have again and again changed their standard, making more and more subjects elective, until now nobody has to do anything that is very difficult simply for the purpose of training the mind, and I regret to say that psychologists have done more to spread the idea that there is no subject that trains the mind for anything else, an opinion which I do not hold in the slightest. If I had my way, no one should graduate from college unless he knew at least what the infini-

tesimal calculus was and what it was for, what relation its invention bore to the history of thought in general, and a few matters of similar import which should be a part of the intellectual equipment of every educated adult. But boys in college are not adults. I sometimes wonder whether "old grads" are adults, either. I have recently heard the opinion expressed that without alcoholic stimulant it will be impossible to hold reunions at Commencement. When I once protested at being regaled at a meeting of a local Harvard Club with a talk by a football coach on the maneuvers of that interesting game, I was asked what other subject there was which was of common interest to college graduates. I replied that in that case I thought the colleges should close.

If we turn to the Army and Navy the case is even worse. The criticisms made by President Eliot on West Point are eminently sound. We have at any rate at the top of our colleges a number of universities where the élite students may engage in graduate work and where much of the work done is of first quality. A very large amount of scientific research is now done in the United States, much of it comparing very well with work that is done anywhere else. But in the Army and Navy we have nothing of the sort. Boys are admitted to West Point or Annapolis, for I shall speak of the two on like footing, who have the merest fragment of elementary education, and in four years they are supposed to be turned out complete officers and gentlemen. If it is considered that part of their course consists of so much mathematics as to take them through the elements of the calculus, it may easily be guessed how deep this knowledge must be.

Within the last few years I have personally visited both the Naval Academy at Annapolis and the Military Academy at West Point, and during the five years of my membership in that at first much over-advertised and lately too much forgotten institution the Naval Consulting Board of the United States I have had the opportunity of meeting many officers of both services. These officers are always extremely agreeable gentlemen, accustomed to the handling of men and thoroughly competent in the ordinary duties of their stations. They are all alike in one thing, however. They have been deprived of the opportunities of a really superior education. Army and Naval officers do not as a rule originate ideas, nor do they contribute to the advancement of science even in their own professions. In France, Germany or Italy it is no rarity to see shoulder straps at scientific meetings. In the United States it is almost un-

heard of. I do not need to mention Napoleon's general Monge who invented the science of descriptive geometry, or Poncelet, who while confined in a Russian prison discovered the projective properties of figures. A long line of French and Italian officers have contributed advances not only to mathematics, but to many of the other sciences. I speak of mathematics, being one of the most difficult, first.

The contribution of the Ecole Polytechnique to the winning of the war was enormous. A French general said to me, "*Sans la Polytechnique, nous ne l'eussions pas fait.*" It was noticeable that during the war it was necessary to call in a large body of professors of mathematics, physics, chemistry, to say nothing of psychology and other subjects, from the universities. These supposedly cloistered individuals contributed in very large measure to the winning of the war, many of them working their galvanometers and other laboratory instruments under German shell fire at the front and winning distinguished honors for so doing. Even the regular Army and Navy were grateful. As one concrete result a number of positions were created in the Army Ordnance Department which were filled by mathematicians, physicists or engineers from civil life.

During my visit to Annapolis, where I was received with the greatest hospitality by the superintendent, who personally conducted me all over the school, when we came to the physical laboratory, as I am a physicist I asked some questions of the young instructor in order to show my interest. He regretted that he was unable to answer; excusing himself because he had but recently come. That night at dinner I could not resist asking the superintendent, who told me that he had brought these officers with him, whether he could make a physicist out of any officer. "Oh," he replied, "they had very distinguished records at sea." I had nothing to say, but it occurred to me that no amount of distinction at sea would have made a physicist of me.

In the Army and Navy the theory is that anybody can teach anything if ordered to. Of such a theory the less said the better. It is high time that this country had a college in which a few élite officers of both the Army and Navy could study together the superior portions of the technical branches of their subjects. They should have as professors the most distinguished scientific men that the country can afford. They need not necessarily wear chickens on their shoulders. It is high time that the feeling of self-sufficiency which impregnates officers of the regular military establishments should be somewhat dissipated. They may as well learn that occasionally a person

not in uniform can give them some advice. It is not so many years ago that a committee from West Point visited the leading colleges of the country and on returning to West Point made the report that they had learned nothing and saw nothing to change. It is to be hoped that the large number of officers who went to Europe during the war and mingled with the officers of other armies may have had their eyes somewhat opened. But, as far as I can learn, the great majority not only of the doughboys, but even of the officers, made no attempt to learn French and did not find out very much about the differences in French ways of education from ours. Still they undoubtedly learned something.

What suggestions can now be made of a positive character for the amelioration of a condition that must shock all those who actually learn the truth? In the first place, the removal of our self-satisfaction. We are not the best educated nation in the world. We do not produce the most original ideas in learning or in invention. We are, to be sure, extremely quick and facile, and that is one of our weaknesses. It is easy to leave a thing until the necessity arises, and then to jump at it and do it. In that way the war was won. But in the case of another war, which God forbid, we shall have many of the things to do over in the same slipshod and backward way. Secondly, we must dispel the illusion that the chief thing in life is to have a good time, an expression which, as I recently heard a charming young Frenchwoman say in a lecture, does not exist in French. Youth is the time for work; youth is the time for beginning to learn. But manhood is the time for the appreciation of learning, for the appreciation of the fact that learning is the chief thing that distinguishes the upper classes from any other classes, that learning has a value of its own and is, like virtue, its own reward. We must improve our elementary schools which are now in dire danger of extinction through the wretched rewards paid, insufficient to attract competent teachers. These schools never were good enough and now bid fair soon to fall almost to zero level. Of course, we hope the times will soon change and compensations return to something like normal. That is not enough. There is no reason that our children should not be as thorough as French children or that graduates of our colleges should not be able to pass the examinations formerly set for Rhodes scholars.

In my opinion it will be necessary to relegate the colleges to the rank of schools and to actually limit the number of people who go to them. The insane desire to increase and in-

crease the size of our colleges must be replaced by a desire to increase the quality even at the expense of numbers. What place in civilization can be attributed to a State which does not realize that the education of its citizens is of supreme importance to the State, and that allows education to be supported by drives to squeeze from the unwilling pockets of graduates of private institutions a sum sufficient to enable their professors to maintain their self-respect?

In a late number of the *Weekly Review* is a letter from the dean of a university of the Middle West. In it he insists upon the importance of the knowledge at headquarters of the number of hours spent by every professor in the classroom and of the number of students there are associated with each professor and with each classroom. I have been expecting this for some time and we shall be called upon to punch clocks.

To my great good fortune I have not spent my life in any such atmosphere. I have been so fortunate as to belong to an institution modelled upon the great institutions abroad in which learning, and particularly scientific learning, was looked upon as the chief desideratum and where research was made the chief object in view. Every member of the instructing staff was stimulated to produce all that he could and to convey the same feeling to every one with whom he came in contact. No one ever came to Clark University unless he wished to become a scholar, unless he thought that he could contribute something to the great structure of human learning.

We hear much in these days of research councils, of organizations of research, of cooperation, of organization, of efficiency, of questionnaires, and of red tape. I hear yet of no corporations for the cooperative production of poetry, of music, of sculpture or of painting. Of course the pupils of Rubens did cooperate in painting so many miles of naked Dutch women, but I suppose it was under the immediate stimulation and supervision of the master, and so it is possible to carry on research. Research is not a matter of bureaus, but of enthusiasm. There is no teacher so good, so stimulating, so productive of enthusiasm as the man who himself is a great contributor to learning.

In my trip last summer I had the good fortune to make the acquaintance of Professor Paul Sabatier, of the University of Toulouse, who has received the Nobel Prize in chemistry and was looked upon, as was perfectly evident, by all his colleagues as the chief adornment of that flourishing university. Even then there was being constructed for him a new laboratory to

accommodate those students whose influx there was due not to athletic prowess, or pride of age, or great buildings or marble palaces, but to the reputation of the master.

When such a spirit as this prevails in all universities of the United States, when professors do not have to act as policemen or judges to portion out punishments and rewards and to spend their time in doing things that are of no importance to the community whatever, when learning is looked upon as a sufficient motive for engaging the attention of the best intellects, and when those financial resources, which we command in a degree unparalleled in the history of the known world, have been devoted to this cause, and when it is thought better to invest twenty million of dollars in laboratories rather than in one battleship devoted exclusively to purposes of destruction, then possibly we may see the United States take the position that her material success entitles her to take among the great nations of the world.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE[1]

FOSSILS AND LIFE

By Dr. F. A. BATHER

PRESIDENT OF THE GEOLOGICAL SECTION

FOR many a long year the relatively simple mechanics of the vertebrate skeleton have been studied by paleontologists and anatomists generally, and have been brought into discussions on the effect of use. The investigation of the mechanical conditions controlling the growth of organisms has recently been raised to a higher plane by Professor D'Arcy Thompson's suggestive book on "Growth and Form." These studies, however, have usually considered the structure of an animal as an isolated machine. We have to realize that an organism should be studied in relation to the whole of its environment, and here form comes in as distinct from structure. That mode of expression, though loose and purely relative, will be generally understood. By "form" one means those adaptations to the surrounding medium, to food, to the mode of motion, and so forth, which may vary with outer conditions while the fundamental structure persists. Though all structures may, conceivably, have originated as such adaptations, those which we call "form" are, as a rule, of later origin. Similar adaptive forms are found in organisms of diverse structure, and produce those similarities which we know as "convergence." To take but one simple instance from the relations of organisms to gravity. A stalked echinoderm naturally grows upright, like a flower, with radiate symmetry. But in the late Ordovician and in Silurian rocks are many in which the body has a curiously flattened leaf-like shape, in which the two faces are distinct, but the two sides alike, and in which this effect is often enhanced by paired outgrowths corresponding in shape if not in structure. Expansion of this kind implies a position parallel to the earth's surface, *i.e.*, at right angles to gravity. The leaf-like form and the balancers are adaptations to this unusual position. Recognition of this enables us to interpret the peculiar features of each genus, to separate the adaptive form from the modified struc-

[1] Extracts from addresses given at the Cardiff Meeting.

ture, and to perceive that many genera outwardly similar are really of quite different origin.

Until we understand the principles governing these and other adaptations—irrespective of the systematic position of the creatures in which they appear—we can not make adequate reconstructions of our fossils, we can not draw correct inferences as to their mode of life, and we can not distinguish the adaptive from the fundamental characters. No doubt many of us, whether paleontologists or neontologists, have long recognized the truth in a general way, and have attempted to describe our material—whether in stone or in alcohol—as living creatures; and not as isolated specimens but as integral portions of a mobile world. It is, however, chiefly to Louis Dollo that we owe the suggestion and the example of approaching animals primarily from the side of the environment, and of studying adaptations as such. The analysis of adaptations in those cases where the stimulus can be recognized and correlated with its reaction (as in progression through different media or over different surfaces) affords sure ground for inferences concerning similar forms of whose life-conditions we are ignorant. Thus Othenio Abel (1916) has analyzed the evidence as to the living squids and cuttle-fish and has applied it to the belemnites and allied fossils with novel and interesting results. But from such analyses there have been drawn wider conclusions pointing to further extension of the study. It was soon seen that adaptations did not come to perfection all at once, but that harmonization was gradual, and that some species had progressed further than others. But it by no means follows that these represent chains of descent. The adaptations of all the organs must be considered, and one seriation checked by another. Thus in 1890, in sketching the probable history of certain crinoids, I pointed out that the seriation due to the migration of the anal plates must be checked by the seriation due to the elaboration of arm-structure, and so on.

In applying these principles we are greatly helped by Dollo's thesis of the Irreversibility of Evolution. It is not necessary to regard this as an absolute Law, subject to no conceivable exception. It is a simple statement of the facts as hitherto observed, and may be expressed thus:

1. In the course of race-history an organism never returns exactly to its former state, even if placed in conditions of existence identical with those through which it has previously passed. Thus, if through adaptation to a new mode of life (as from walking to climbing) a race loses organs which were highly

useful to it in the former state, then, if it ever reverts to that former mode of (as from climbing to walking), those organs never return, but other organs are modified to take their place.

2. But (continues the Law), by virtue of the indestructibility of the past, the organism always preserves some trace of the intermediate stages. Thus, when a race reverts to its former state, there remain the traces of those modifications which its organs underwent while it was pursuing another mode of existence.

The first statement imposes a veto on any speculations as to descent that involve the reappearance of a vanished structure. It does not interfere with the cases in which old age seems to repeat the characters of youth, as in Ammonites, for here the old-age character may be similar, but obviously is not the same. The second statement furnishes a guide to the mode of life of the immediate ancestors, and is applicable to living as well as to fossil forms. It is from such persistent adaptive characters that some have inferred the arboreal nature of our own ancestors, or even of the ancestors of all mammals. To take but a single point, Dr. W. D. Matthew[1] finds traces of a former opposable thumb in several early Eocene mammals, and features dependent on this in the same digit of all mammals where it is now fixed.

THE STUDY OF HABITAT

The natural history of marine invertebrates is of particular interest to the geologist, but its study presents peculiar difficulties. The marine zoologist has long recognized that his early efforts with trawl and dredge threw little light on the depth in the sea frequented by his captures. The surface floaters, the swimmers of the middle and lower depths, and the crawlers on the bottom were confused in a single haul, and he has therefore devised means for exploring each region separately. The geologist, however, finds all these faunas mixed in a single deposit. He may even find with them the winged creatures of the air, as in the insect beds of Gurnet Bay, or the remains of estuarine and land animals.

Such mixtures are generally found in rocks that seem to have been deposited in quiet land-locked bays. Thus in a Silurian rock near Visby, Gotland, have been found creatures of such diverse habitat as a scorpion, a possibly estuarine *Pterygotus*, a large barnacle, and a crinoid of the delicate form usually associated with clear deep water. The lagoons of Solenhofen have preserved a strange mixture of land and sea life,

[1] 1904, *Amer. Natural.*, XXXVIII., 813.

without a trace of fresh or brackish water forms. *Archaeopteryx,* insects, flying reptiles, and creeping reptiles represent the air and land fauna; jelly-fish and the crinoids *Saccocoma* are true open-water wanderers; sponges and stalked crinoids were sessile on the bottom; starfish, sea-urchins, and worms crawled on the sea-floor; king-crabs, lobsters, and worms left their tracks on mud-flats; cephalopods swam at various depths; fishes ranged from the bottom mud to the surface waters. The Upper Ordovician Starfish bed of Girvan contains not only the crawling and wriggling creatures from which it takes its name, but stalked echinoderms adapted to most varied modes of life, swimming and creeping trilobites, and indeed representatives of almost all marine levels.

In the study of such assemblages we have to distinguish between the places of birth, of life, of death, and of burial, since, though these may all be the same, they may also be different. The echinoderms of the Starfish bed further suggest that closer discrimination is needed between the diverse habitats of bottom forms. Some of these were, I believe, attached to sea-weed; others grew up on stalks above the bottom; others clung to shells or stones; others lay on the top of the sea-floor; others were partly buried beneath its muddy sand; others may have groveled beneath it, connected with the overlying water by passages. Here we shall be greatly helped by the investigations of C. G. J. Petersen and his fellow-workers of the Danish Biological Station.[2] They have set an example of intensive study which needs to be followed elsewhere. By bringing up slabs of the actual bottom, they have shown that, even in a small area, many diverse habitats, each with its peculiar fauna, may be found, one superimposed on the other. Thanks to Petersen and similar investigators, exact comparison can now take the place of ingenious speculation. And that this research is not merely fascinating in itself, but illuminatory of wider questions, follows from the consideration that analysis of faunas and their modes of life must be a necessary preliminary to the study of migrations and geographical distribution.

THE TEMPO OF EVOLUTION

We have not yet done with the results that may flow from an analysis of adaptations. Among the many facts which, when considered from the side of animal structure alone, lead to transcendental theories with Greek names, there is the observa-

[2] See especially in his summary, "The Sea Bottom and its Production of Fish Food," Copenhagen, 1918.

tion that the relative rate of evolution is very different in races living at the same time. Since their remains are found often side by side, it is assumed that they were subject to the same conditions, and that the differences of speed must be due to a difference of internal motive force. After what has just been said you will at once detect the fallacy in this assumption. Professor Abel has recently maintained that the varying tempo of evolution depends on the changes in outer conditions. He compares the evolution of whales, sirenians, and horses during the Tertiary Epoch, and correlates it with the nature of the food. Roughly to summarize, he points out that from the Eocene onwards the sirenians underwent a steady, slow change, because, though they migrated from land to sea, they retained their habit of feeding on the soft water-plants. The horses, though they remained on land, display an evolution at first rather quick, then slower, but down to Pliocene times always quicker than that of the sirenians; and this is correlated with their change into eaters of grain, and their adaptation to the plains which furnish such food. The whales, like the sirenians, migrated at the beginning of the Tertiary from land to sea; but how different is their rate of evolution, and into what diverse forms have they diverged! At first they remained near the coasts, keeping to the ancestral diet, and, like the sirenians, changing but slowly. But the whales were flesh-eaters, and soon they took to hunting fish, and then to eating large and small cephalopods; hence from the Oligocene onwards the change was very quick, and in Miocene times the evolution was almost tempestuous. Finally, many whales turned to the swallowing of minute floating organisms, and from Lower Pliocene times, having apparently exhausted the possibilities of ocean provender, they changed with remarkable slowness.

Whether such changes of food or of other habits of life are, in a sense, spontaneous, or whether they are forced on the creatures by changes of climate and other conditions, makes no difference to the facts that the changes of form are a reaction to the stimuli of the outer world and that the rate of evolution depends on those outer changes.

Whether we have to deal with similar changes of form taking place at different times or in different places, or with diverse changes affecting the same or similar stocks at the same time and place, we can see the possibility that all are adaptations to a changing environment. There is then reason for thinking that ignorance alone leads us to assume some inexplicable force urging the races this way or that, to so-called advance or to apparent degeneration, to life or to death.

THE RHYTHM OF LIFE

The comparison of the life of a lineage to that of an individual is, up to a point, true and illuminating; but when a lineage first starts on its independent course (which really means that some individuals of a pre-existing stock enter a new field), then I see no reason to predict that it will necessarily pass through periods of youth, maturity, and old age, that it will increase to an acme of numbers, of variety, or of specialization, and then decline through a second childhood to ultimate extinction. Still less can we say that, as the individuals of a species have their allotted span of time, long or short, so the species or the lineage has its predestined term. The exceptions to those assertions are indeed recognized by the supporters of such views, and they are explained in terms of rejuvenescence, rhythmic cycles, or a grand despairing outburst before death. This phraseology is delightful as metaphor, and the conceptions have had their value in promoting search for confirmatory or contradictory evidence. But do they lead to any broad and fructifying principle? When one analyses them one is perpetually brought up against some transcendental assumption, some unknown entelechy that starts and controls the machine, but must forever evade the methods of our science.

The facts of recurrence, of rhythm, of rise and fall, of marvelous efflorescences, of gradual decline, or of sudden disappearances, all are incontestable. But if we accept the intimate relation of organism and environment, we shall surmise that on a planet with such a geological history as ours, with its recurrence of similar physical changes, the phenomena of life must reflect the great rhythmic waves that have uplifted the mountains and lowered the deeps, no less than every smaller wave and ripple that has from age to age diversified and enlivened the face of our restless mother.

To correlate the succession of living forms with all these changes is the task of the paleontologist. To attempt it he will need the aid of every kind of biologist, every kind of geologist. But this attempt is not in its nature impossible, and each advance to the ultimate goal will, in the future as in the past, provide both geologist and biologist with new light on their particular problems. When the correlation shall have been completed, our geological systems and epochs will no longer be defined by gaps in our knowledge, but will be the true expression of the actual rhythm of evolution. Lyell's great postulate of the uniform action of nature is still our guide; but we have ceased to confound uniformity with monotony. We return,

though with a difference, to the conceptions of Cuvier, to those numerous and relatively sudden revolutions of the surface of the globe which have produced the corresponding dynasties in its succession of inhabitants.

The Future

The work of a systematic paleontologist, especially of one dealing with rare and obscure fossils, often seems remote from the thought and practice of modern science. I have tried to show that it is not really so. But still it may appear to some to have no contact with the urgent problems of the world outside. That also is an error. Whether the views I have criticized or those I have supported are the correct ones is a matter of practical importance. If we are to accept the principle of predetermination, or of blind growth-force, we must accept also a check on our efforts to improve breeds, including those of man, by any other means than crossing and elimination of unfit strains. In spite of all that we may do in this way, there remain those decadent races, whether of ostriches or human beings, which "await alike the inevitable hour." If, on the other hand, we adopt the view that the life-history of races is a response to their environment, then it follows, no doubt, that the past history of living creatures will have been determined by conditions outside their control, it follows that the idea of human progress as a biological law ceases to be tenable; but, since man has the power of altering his environment and of adapting racial characters through conscious selection, it also follows that progress will not of necessity be followed by decadence; rather that, by aiming at a high mark, by deepening our knowledge of ourselves and of our world, and by controlling our energy and guiding our efforts in the light of that knowledge, we may prolong and hasten our ascent to ages and to heights as yet beyond prophetic vision.

HEREDITY

By Miss E. R. SAUNDERS

PRESIDENT OF THE BOTANICAL SECTION

By the term Inheritance we are accustomed to signify the obvious fact of the resemblance displayed by all living organisms between offspring and parents, as the direct outcome of the contributions received from the two sides of the pedigree at fertilization: to indicate, in fact, owing to lack of knowledge of the workings of the hereditary process, merely the *visible*

consequence—the final result of a chain of events. Now, however, that we have made a beginning in our analysis of the stages which culminate in the appearance of any character, a certain looseness becomes apparent in our ordinary use of the word Heredity, covering as it does the two concomitant essentials, genetic potentiality and somatic expression—a looseness which may lead us into the paradoxical statement that inheritance is wanting in a case in which, nevertheless, the evidence shows that the genetic constitution of the children is precisely like that of the parents. When we say that a character is inherited no ambiguity is involved, because the appearance of the character entails the inheritance of the genetic potentiality. But when a character is stated not to be inherited it is not thereby indicated whether this result is due to environmental conditions, to genetic constitution, or to both causes combined. That we are now able in some measure to analyze the genetic potentialities of the individual is due to one of those far-reaching discoveries which change our whole outlook and bring immediately in their train a rapidly increasing array of new facts, falling at once into line with our new conceptions, or by some orderly and constant discrepancy pointing a fresh direction for attack. A historical survey of the steps by which we have advanced to the present state of our knowledge of Heredity has so frequently been given during the last twenty years that the briefest reference to this part of my subject will suffice.

The earliest attempts to frame some general law which would coordinate and explain the observed facts of inheritance were those of Galton and Pearson. Galton's observations led him to formulate two principles which he believed to be capable of general application—the Law of Ancestral Heredity and the Law of Regression. The Law of Ancestral Heredity was intended to furnish a general expression for the sum of the heritage handed on in any generation to the succeeding offspring. Superposed upon the working of this law were the effects of the Law of Regression, in which the average deviation from the mean of a whole population of any fraternal group within that population was expressed in terms of the average deviation of the parents. These expressions represent statements of averages which, in so far as they apply, hold only when large numbers are totaled together. They afford no means of certain prediction in the individual case. These and all similar statistical statements of the effects of inheritance take no account of the essentially physiological nature of this as of all other processes in the living organism. They leave us unenlightened on the fundamental

question of the nature of the means by which the results we witness came to pass. We obtain from them, as from the melting-pot, various new products whose properties are of interest from other viewpoints, but, corresponding to no biological reality, they have failed to bring us nearer to our goal—a fuller comprehension of the workings of the hereditary mechanism. Progress in this direction has resulted from the opposite method of inquiry—the study of a single character in a single line of descent, the method which deals with the unit in place of the mass. The revelation came with the opening of the present coloring matter anthocyanin in the petals of plants such as the stock and sweet pea. Our proof that two factors (at least) are here involved is obtained when we find that two true breeding forms devoid of color yield colored offspring when mated together. In this case the two complementary factors are carried, one by each of the two crossed forms. When both factors meet in the one individual, color is developed. We have in such cases the solution of the familiar, but previously unexplained, phenomenon of Reversion. Confirmatory evidence is afforded when among the offspring of such cross-bred individuals we find the simple 3 to 1 ratio of the one-factor difference replaced by a ratio of 9 to 7. Similarly we deduce from a ratio of 27 to 37 that three factors are concerned, from a ratio of 81 to 175 four factors, and so on. The occurrence of these higher ratios proves that the hereditary process follows the same course whatever the number of factors controlling the character in question.

And here I may pause to dwell for a moment upon a point of which it is well that we should remind ourselves from time to time, since, though tacitly recognized, it finds no explicit expression in our ordinary representation of genetic relations. The method of factorial analysis based on the results of interbreeding enables us to ascertain the least possible number of genetic factors concerned in controlling a particular somatic character, but what the total of such factors actually is we can not tell, since our only criterion is the number by which the forms we employ are found to differ. How many may be common to these forms remains unknown. In illustration I may take the case of surface character in the genera *Lychnis* and *Matthiola*. In *L. vespertina* the type form is hairy; in the variety *glabra*, recessive to the type, hairs are entirely lacking. Here all glabrous individuals have so far proved to be similar in constitution, and when bred with the type give a 3 to 1 ratio in F_2.[1] We speak of hairiness in this case, therefore, as being a

[1] Report to the Evolution Committee, Royal Society, I., 1902.

one-factor character. In the case of *Matthiola incana v. glabra,* of which many strains are in cultivation, it so happened that the commercial material originally employed in these investigations contained all the factors since identified as present in the type and essential to the manifestation of hairiness except one. Hence it appeared at first that here also hairiness must be controlled, as in *Lychnis,* by a single factor. But further experiment revealed the fact that though the total number of factors contained in these glabrous forms was the same, the respective factorial combinations were not identical. By interbreeding these and other strains obtained later, hairy F_1 cross-breds were produced giving ratios in F_2 which proved that at least four distinct factors are concerned.[2] Whereas, then, the glabrous appearance in *Lychnis* always indicates the loss (if for convenience we may so represent the nature of the recessive condition) *of one and the same factor,* analysis in the Stock shows that the glabrous condition results if *any factor out of a group of four* is represented by its recessive allelomorph. Hence we describe hairiness in the latter case as a four-factor character.

It will be apparent from the cases cited that we can not infer from the genetic analysis of one type that the factorial relations involved are the same for the corresponding character in another. That this should be so in wholly unrelated plants is not, perhaps, surprising, but we find it to be true also where the nature of the characteristic and the relationship of the types might have led us to expect uniformity. This is well seen in the case of a morphological feature distinctive of the N. O. Gramineæ. The leaf is normally ligulate, but individuals are occasionally met with in which the ligule is wanting. In these plants, as a consequence, the leaf blade stands nearly erect instead of spreading out horizontally. Nilsson-Ehle[3] discovered that in oats there are at least four and possibly five distinct factors determining ligule formation, all with equal potentialities in this direction. Hence, only when the complete series is lacking is the ligule wanting. In mixed families the proportion of ligulate to non-ligulate individuals depends upon the number of these ligule-producing factors contained in the dominant parent. Emerson[4] found, on the other hand, that in maize mixed families showed constantly a 3 to 1 ratio, indicating the existence of only one controlling factor.

[2] *Proc. Roy. Soc.,* B, Vol. 85, 1912.

[3] "Kreuzungsuntersuchungen an Hafer und Weizen," Lund, 1909.

[4] Annual Report of the Agricultural Experiment Station of the University of Nebraska, 1912.

From time to time the objection has been raised that the Mendelian type of inheritance is not exhibited in the case of specific characters. That no such sharp line of distinction can be drawn between the behavior of varietal and specific features has been repeatedly demonstrated. As a case in point and one of the earliest in which clear proof of Mendelian segregation was obtained, we may instance *Datura*. The two forms, *D. Stramonium* and *D. Tatula*, are ranked by all systematists as distinct species. Among other specific differences is the flower color. The one form has purple flowers, the other pure white. In the case of both species a variety *inermis* is known in which the prickles characteristic of the fruit in the type are wanting. It has been found that in whatever way the two pairs of opposite characters are combined in a cross between the species, the F_2 generation is mixed, comprising the four possible combinations in the proportions which we should expect in the case of two independently inherited pairs of characters, when each pair of opposites shows the dominant-recessive relation. Segregation is as sharp and clean in the specific character flower color as in the varietal character of the fruit. Among the latest additions to the list of specific hybrids showing Mendelian inheritance, those occurring in the genus *Salix* are of special interest, since heretofore the data available had been interpreted as conflicting with the Mendelian conception. The recent observations of Heribert-Nilson[5] show that those characters which are regarded by systematists as constituting the most distinctive marks of the species are referable to an extremely simple factorial system, and that the factors mendelize in the ordinary way. Furthermore, these specific-character factors control not only the large constant *morphological features*, but *fundamental reactions* such as those determining the condition of physiological equilibrium and vitality in general. In so far as any distinction can be drawn between the behavior of factors determining the varietal as opposed to the specific characters of the systematist, Heribert-Nilsson concludes that the former are more localized in their action, while the latter produce more diffuse results, which may affect almost all the organs and functions of the individual, and thus bring about striking alterations in the general appearance. *S. caprea*, for example, is regarded as the reaction product of two distinct factors which together control the leaf-breadth character, but which also affect, each separately and in a different way, leaf form, leaf color, height,

[5] "Experimentelle Studien über Variabilität, Spaltung, Artbildung und Evolution in der Gattung Salix," 1918.

and the periodicity of certain phases. We can not, however, draw a hard-and-fast line between the two categories. The factor controlling a varietal characteristic often produces effects in different parts of the plant. For example, the factors which lead to the production of a colored flower no doubt also in certain cases cause the tinging seen in the vegetative organs, and affect the color of the seed. Heribert-Nilsson suggests that fertility between species is a matter of close similarity in genotypic (factorial) constitution rather than of outward morphological resemblance. Forms sundered by the systematist on the ground of gross differences in certain anatomical features may prove to be more nearly related because the differentiating factors happen to control less conspicuous features.

THE SUPPLY OF OXYGEN TO THE TISSUES

By J. R. BARCROFT

PRESIDENT OF THE PHYSIOLOGICAL SECTION

PROMINENT among the pathological conditions which claimed attention during the war was that of insufficient oxygen supply to the tissues, or anoxæmia. For this there were several reasons; on the one hand, anoxæmia clearly was a factor to be considered in the elucidation of such conditions as are induced by gas poisoning, shock, etc. On the other hand, knowledge had just reached the point at which it was possible to discuss anoxæmia on a new level. It is not my object in the present address to give any account of war-physiology—the war has passed, and I, for one, have no wish to revive its memories, but anoxæmia remains, and, as it is a factor scarcely less important in peace than in war pathology, I think I shall not do wrong in devoting an hour to its consideration.

The object of my address, therefore, will be to inquire, and, if possible, to state, where we stand; to sift, if I can, the knowledge from the half-knowledge; to separate what is ascertained as the result of unimpeachable experiment from what is but guessed on the most likely hypothesis. In war it was often necessary to act on defective information, because action was necessary and defective information was the best that was to be had. In this, as in many other fields of knowledge, the whole subject should be reviewed, the hypotheses tested experimentally, and the gaps filled in. The sentence which lives in my mind as embodying the problem of anoxæmia comes from the

pen of one who has given more concentrated thought to the subject than perhaps any other worker—Dr. J. S. Haldane. It runs, "Anoxæmia not only stops the machine, but wrecks the machinery." This phrase puts the matter so clearly that I shall commence by an inquiry as to the limits within which it is true.

Anything like complete anoxæmia stops the machine with almost incredible rapidity. It is true that the breath can be held for a considerable time, but it must be borne in mind that the lungs have a volume of about three liters at any moment, that they normally contain about half a liter of oxygen, and that this will suffice for the body at rest for upwards of two minutes. But get rid of the residual oxygen from the lungs only to the very imperfect extent which is possible by the breathing of some neutral gas, such as nitrogen, and you will find that only with difficulty will you endure half a minute. Yet even such a test gives no real picture of the impotence of the machine—which is the brain—to "carry on" in the absence of oxygen. For, on the one hand, nearly a quarter of a minute elapses before the reduced blood gets to the capillary in the brain, so that the machine has only carried on for the remaining quarter of a minute; on the other hand, the arterial blood under such circumstances is far from being completely reduced—in fact, it has very much the composition of ordinary venous blood, which means that it contains about half its usual quotum of oxygen. It seems doubtful whether complete absence of oxygen would not bring the brain to an instantaneous standstill. So convincing are the experimental facts to any one who has tested them for himself, that I will not further labor the power of anoxæmia to stop the machine. I will, however, say a word about the assumption which I have made that the machine in this connection is the brain.

It can not be stated too clearly that anoxæmia in the last resort must affect every organ of the body directly. Stoppage of the oxygen supply is known, for instance, to bring the perfused heart to a standstill, to cause a cessation of the flow of urine, to produce muscular fatigue, and at last immobility, but from our present standpoint these effects of anoxæmia seem to me to be out of the picture, because the brain is so much the most sensitive to oxygen want. Therefore, if the problem is the stoppage of the machine due to an insufficient general supply of oxygen, I have little doubt that the machine stops because the brain stops, and here at once I am faced with the question how far is this assumption and how far is it proven fact? I freely answer that research in this field is urgent; at present there is

too great an element of assumption, but there is also a certain amount of fact.

To what extent does acute anoxæmia in a healthy subject wreck the machinery as well as stop the machine? By acute anoxæmia I mean complete or almost complete deprivation of oxygen which, in the matter of time, is too short to prove fatal. It is not easy to obtain quite clear-cut experiments in answer to the above question. No doubt many data might be quoted of men who have recovered from drowning, etc. Such data are complicated by the fact that anoxæmia has only been a factor in their condition; other factors, such as accumulation of carbonic acid, may also have contributed to it. The remarkable fact about most of them, however, is the slightness of the injury which the machine has suffered. These data, therefore, have a value in so far as they show that a very great degree of anoxæmia, if acute and of short duration, may be experienced with but little wreckage to the machine. They have but little value in showing that such wreckage is due to the anoxæmia, because the anoxæmia has not been the sole disturbance.

. . . .

It is rather fashionable at present to say that "the whole question of acidosis and anoxæmia is in a hopeless muddle." To this I answer that, if it is in a muddle, I believe the reason to be largely because schools of thought have rallied round words and have taken sides under the impression that they have no common ground. The "muddle," in so far as it exists, is not, I think, by any means hopeless; but I grant freely enough that we are rather at the commencement than at the end of the subject, and that much thought and much research must be given, firstly, in getting accurate data, and, secondly, on relating cause and effect, before the whole subject will seem simple. No effort should be spared to replace indirect by direct measurements. My own inference with regard to changes of the reaction of the blood, based on interpretations of the dissociation curve, should be checked by actual hydrogen ion measurements, as has been done by Hasselbach and is being done by Donegan and Parsons. Meakins also is, I think, doing great work by actually testing the assumptions made by Haldane and himself as regards the oxygen in arterial blood.

For the anoxic type of anoxæmia two forms of compensation at once suggest themselves. The one is increased hemoglobin in the blood; the other is increased blood-flow through the tissues. Let us, along the lines of the calculations already made, endeavor to ascertain how far these two types of compensation

will really help. To go back to the extreme anoxic case already cited, in which the hemoglobin was 66 per cent. saturated, let us, firstly, see what can be accomplished by an increase of the hemoglobin value of the blood. Such an increase takes place, of course, at high altitudes. Let us suppose that the increase is on the same grand scale as the anoxæmia, and that it is sufficient to restore the actual quantity of oxygen in one c.c. of blood to the normal. This, of course, means a rise in the hemoglobin value of the blood from 100 to 150 on the Gowers' scale. Yet even so great an increase in the hemoglobin will only increase the oxygen taken up in the capillary from each c.c. of blood from .031 to .036 c.c., and will therefore leave it far short of the .06 c.c. which every cubic centimeter of normal blood was giving to the tissue. So much, then, for increased hemoglobin. It gives a little, but only a little, respite. Let us turn, therefore, to increased blood-flow.

In the stagnant type of anoxæmia the principal change which is seen to take place is an increase in the quantity of hemoglobin per cubic millimeter of blood.

This increase is secondary to a loss of water in the tissues, the result in some cases, as appears from the work of Dale, Richards, and Laidlaw, of a formation of histamine in the tissues. Whether this increase of hemoglobin is to be regarded as merely an accidental occurrence or as a compensation is difficult to decide at present. Roughton's calculations rather surprised us by indicating that increased hemoglobin acted less efficiently as a compensatory mechanism than we had expected. This conclusion may have been due to the inaccuracy of our assumptions. I must therefore remind you that much experimental evidence is required before the assumptions which are made above are anything but assumptions. But, so far as the evidence available at the present time can teach any lesson, that lesson is this: The only way of dealing satisfactorily with the anoxic type of anoxæmia is to abolish it by in some way supplying the blood with oxygen at a pressure sufficient to saturate it to the normal level.

It has been maintained strenuously by the Oxford school of physiologists that Nature actually did this; that when the partial pressure in the air-cells of the lung was low the cellular covering of that organ could clutch at the oxygen and force it into the blood at an unnatural pressure, creating a sort of forced draught. This theory, as a theory, has much to recommend it. I am sorry to say, however, that I can not agree with it on the present evidence. I will only make a passing allusion to the

experiment which I performed in order to test the theory, living for six days in a glass respiration-chamber in which the partial pressure of oxygen was gradually reduced until it was at its lowest—about 45 mm. Such a pressure, if the lung was incapable of creating what I have termed a forced draught, would mean an oxygen pressure of 38.40 mm. of mercury in the blood, a change sufficient to make the arterial blood quite dark in color, whereas did any considerable forced draught exist, the blood in the arteries would be quite bright in color. Could we but see the blood in the arteries, its appearance alone would almost give the answer as to whether or no oxygen was forced, or, in technical language, secreted, through the lung wall. And, of course, we could see the blood in the arteries by the simple process of cutting one of them open and shedding a little into a closed glass tube. To the surgeon this is not a difficult matter, and it was, of course, done. The event showed that the blood was dark, and the most careful analyses failed to discover any evidence that the body can force oxygen into the blood in order to compensate for a deficiency of that gas in the air.

Yet the body is not quite powerless. It can, by breathing more deeply, by increasing the ventilation of the lungs, bring the pressure of oxygen in the air cells closer to that in the atmosphere breathed than would otherwise be the case. I said just now that the oxygen in my lungs dropped to a minimal pressure of 45 mm.; but it did not remain at that level. When I bestirred myself a little it rose, as the result of increased ventilation of the lung, to 56 mm., and at one time, when I was breathing through valves, it reached 68 mm. Nature will do something, but what Nature does not do should be done by artifice. Exploration of the condition of the arterial blood is only in its infancy, yet many cases have been recorded in which in illness the arterial blood has lacked oxygen as much as or more than my own did in the respiration chamber when I was lying on the last day, with occasional vomiting, racked with headache, and at times able to see clearly only as an effort of concentration. A sick man, if his blood is as anoxic as mine was, can not be expected to fare better as the result, and so he may be expected to have all my troubles in addition to the graver ones which are, perhaps, attributable to some toxic cause. Can he be spared the anoxæmia? The result of our calculations, so far, points to the fact that the efficient way of combating the anoxic condition is to give oxygen. During the war it was given with success in the field in cases of gas-poisoning, and also special wards were formed on a small scale in this country in which the level

of oxygen in the atmosphere was kept up to about 40 per cent., with great benefit to a large percentage of the cases. The practise then inaugurated is being tested at Guy's Hospital by Dr. Hunt, who administered the treatment during the war.

Nor are the advantages of oxygen respiration confined to pathological cases. One of the most direct victims of anoxic anoxæmia is the airman who flies at great heights. Everything in this paper tends to show that to counteract the loss of oxygen which he sustains at high altitudes there is but one policy, namely, to provide him with an oxygen equipment which is at once as light and as efficient as possible—a consummation for which Haldane has striven unremittingly. And here I come to the personal note on which I should like to conclude. In the pages which I have read views have been expressed which differ from those which he holds in matters of detail—perhaps in matters of important detail. But Haldane's teaching transcends mere detail. He has always taught that the physiology of to-day is the medicine of to-morrow. The more gladly, therefore, do I take this opportunity of saying how much I think medicine owes and will owe, to the inspiration of Haldane's teaching.

INTENSIVE CULTIVATION

By Professor FREDERICK KEEBLE

PRESIDENT OF THE AGRICULTURAL SECTION

THERE is, so far as I can discover, no reason—save one—why I should have been called upon to assume the presidency of the Agricultural Section of the British Association, or why I should have been temerarious enough to accept so high an honor and such a heavy load of responsibility. For upon the theme of Agriculture as commonly understood I could speak, were I to speak at all, but as a scribe and not as one in authority. The one reason, however, which must have directed the makers of presidents in their present choice is, I believe, so cogent that despite my otherwise unworthiness I dared not refuse the invitation. It is that, in appointing me, agriculturists desired to indicate the brotherhood which they feel with intensive cultivators. As properly proud sisters of an improved tale they have themselves issued an invitation to the Horticultural Cinderella to attend their party, and in conformity with present custom, which requires each lady to bring her partner, I am here as her friend.

Nor could any invitation give me greater pleasure: for my devotion to Horticulture is profound and my affection that of a lover. My only fear is lest I should weary my hosts with her praises, for in conformity with this interpretation I propose to devote my address entirely to Horticulture—to speak of its performance during the war and of its immediate prospects.

Although that which intensive cultivators accomplished during the war is small in comparison with the great work performed by British agriculturists, yet nevertheless it is in itself by no means inconsiderable, and is, moreover, significant and deserves a brief record. That work may have turned and probably did turn the scale between scarcity and sufficiency; for, as I am informed, a difference of 10 per cent. in food supplies is enough to convert plenty into dearth. Seen from this standpoint the war-work accomplished by the professional horticulturist—the nurseryman, the florist, the glass-house cultivator, the fruit-grower and market gardener, and by the professional and amateur gardener and allotment holder assumes a real importance, albeit that the sum total of the acres they cultivated is but a fraction of the land which agriculturists put under the plough.

As a set-off against the relative smallness of the acreage brought during the war under intensive cultivation for food purposes, it is to be remembered that the yields per acre obtained by intensive cultivators are remarkably high. For example, skilled onion-growers compute their average yield at something less than 5 tons to the acre. A chrysanthemum-grower who turned his resources from the production of those flowers to that of onion obtained over an area of several acres a yield of 17 tons per acre. The average yield of potatoes under farm conditions in England and Wales is a little over 6 tons to the acre, whereas the army gardeners in France produced, from Scotch seed of Arran Chief which was sent to them, crops of 14 tons to the acre. Needless to say, such a rate of yield as this is not remarkable when compared with that obtained by potato-growers in the Lothians or in Lincolnshire, but it is nevertheless noteworthy as an indication of what I think may be accepted as a fact, that the average yields from intensive cultivation are about double those achieved by extensive methods.

The reduction of the acreage under soft fruits—strawberries, raspberries, currants, and gooseberries—which took place during the war gives some measure of the sacrifices—partly voluntary, partly involuntary—made by fruit-growers to the cause of war-food production. The total area under soft fruits

was 55,560 acres in 1913, by 1918 it had become 42,415, a decrease of 13,145 acres, or about 24 per cent. As would be expected, the reduction was greatest in the case of strawberries, the acreage of which fell from 21,692 in 1913 to 13,143 in 1918, a decrease of 8,549 acres, or about 40 per cent. It is unfortunate that bad causes often have best propagandas, for were the public made aware of such facts as these they would realize that the present high prices of soft fruits are of the nature of deferred premiums on war-risk insurances with respect to which the public claims were paid in advance and in full.

I should add that the large reduction of the strawberry acreage is a measure no less of the shortsightedness of official than of the public spirit of fruit-growers; for in the earlier years of the war many counties issued compulsory orders requiring the grubbing up and restriction of planting of fruit, and I well remember that one of my first tasks as Controller of Horticulture was to intervene with the object of convincing the enthusiasts of corn production that, in war, some peace-time luxuries become necessaries and that, to a sea-girt island beset by submarines, home-grown fruit most certainly falls into this category.

Those who were in positions of responsibility at that time will not readily forget the shifts to which they were put to secure and preserve supplies of any sorts of fruit which could be turned into jam—the collection of blackberries, the installation of pulping factories which Mr. Martin and I initiated, and the rushing of supplies of scarcely set jam to great towns, the populace of which, full of a steadfast fortitude in the face of military misfortune, was ominously losing its sweetness of disposition owing to the absence of jam and the dubiousness of the supply and quality of margarine.

But though the public lost in one direction it gained in another, and the reduction of the soft-fruit acreage meant—reckoned in terms of potatoes—an augmentation of supplies to the extent of over 100,000 tons. Equally notable was the contribution to food production made by the florists and nurserymen in response to our appeals. An indication of their effort is supplied by figures which, as president of the British Florists' Federation, Mr. George Munro—whose invaluable work for food production deserves public recognition—caused to be collected. They relate to the amount of food production undertaken by 100 leading florists and nurserymen. These men put 1,075 acres, out of a total of 1,775 acres used previously for flower-growing, to the purpose of food production, and they put

142 acres of glass out of a total of 218 acres to like use. I compute that their contribution amounted to considerably more than 12,000 tons of potatoes and 5,000 tons of tomatoes.

The market growers of Evesham and other districts famous for intensive cultivation also did their share by substituting for luxury crops, such as celery, those of greater food value, and even responded to our appeals to increase the acreage under that most chancy of crops—the onion, by laying down an additional 4,000 acres and thereby doubling a crop which more than any others supplies accessory food substances to the generality of the people.

In this connection the yields of potatoes secured by Germany and this country during the war period are worthy of scrutiny.

The pre-war averages were: Germany 42,450,000 tons, United Kingdom 6,950,000 tons; and the figures for 1914 were: Germany 41,850,000 tons, United Kingdom 7,476,000 tons.

Germany's supreme effort was made in 1915 with a yield of 49,570,000 tons, or about 17 per cent. above average. In that year our improvement was only half as good as that of Germany: our crop of 7,540,000 tons bettering our average by only 8 per cent. In 1916 weather played havoc with the crops in both countries, but Germany suffered most. The yield fell to 20,550,000 tons, a decrease of more than 50 per cent., whilst our crop was down to 5,469,000 tons, a falling off of only 20 per cent. In the following year Germany could produce no more than 39,500,000 tons, or a 90 per cent. crop, whereas the United Kingdom raised 8,604,000 tons, or about 24 per cent. better than the average. Finally, whereas with respect to the 1918 crop in Germany no figures are available, those for the United Kingdom indicate that the 1917 crop actually exceeded that of 1918.

There is much food for thought in these figures, but my immediate purpose in citing them is to claim that of the million and three quarter tons increase in 1917 and 1918 a goodly proportion must be put to the credit of the intensive cultivator.

I regret that no statistics are available to illustrate the wartime food production by professional and amateur gardeners. That it was great I know, but how great I am unable to say. This however I can state, that from the day before the outbreak of hostilities, when, with the late Secretary of the Royal Horticultural Society, I started the intensive food-production campaign by urging publicly the autumn sowing of vegetables—a practice both then and now insufficiently followed—the amateur and professional gardeners addressed themselves to the work of producing food with remarkable energy and success. No less

remarkable and successful was the work of the old and new allotment holders, so much so indeed that at the time of the Armistice there were nearly a million and a half allotment holders cultivating upwards of 125,000 acres of land: an allotment for every five households in England and Wales. It is a pathetic commentary on the Peace that Vienna should find itself obliged to do now what was done here during the war—namely, convert its parks and open spaces into allotments in order to supplement a meager food supply.

This brief review of war-time intensive cultivation would be incomplete were it to contain no reference to intensive cultivation by the armies at home and abroad. From small beginnings, fostered by the distribution by the Royal Horticultural Society of supplies of vegetable seeds and plants to the troops in France, army cultivation assumed under the direction of Lord Harcourt's Army Agricultural Committee extraordinarily large dimensions: a bare summary must suffice here, but a full account may be found in the report presented by the Committee to the House of Parliament and published as a Parliamentary Paper.

In 1918 the armies at home cultivated 5,869 acres of vegetables. In the summer of that year the camp and other gardens of our armies in France were producing 100 tons of vegetables a day. These gardens yielded, in 1918, 14,000 tons of vegetables, worth, according to my estimate, a quarter of a million pounds sterling, but worth infinitely more if measured in terms of benefit to the health of the troops.

As the result of General Maude's initiative, the forces in Mesopotamia became great gardeners, and in 1918 produced 800 tons of vegetables, apart altogether from the large cultivations carried out by His Majesty's Forces in that wonderfully fertile land. In the same year the forces at Salonika had about 7,000 acres under agricultural and horticultural crops, and raised produce which effected a saving of over 50,000 shipping tons.

Even from this brief record it will, I believe, be conceded that intensive cultivation played a useful and significant part in the war: what, it may be asked, is the part which it is destined to play in the future? So far as I am able to learn, there exist in this country two schools of thought or opinion on the subject of the prospects of intensive cultivation, the optimistic and the pessimistic school. The former sees visions of large communities of small cultivators colonizing the countryside of England, increasing and multiplying both production and them-

selves, a numerous, prosperous and happy people and a sure shield in time of war against the menace of submarines and starvation. Those on the other hand who take the pessimistic view, point to the many examples of smallholders who "plough with pain their native lea and reap the labor of their hands" with remarkably small profit to themselves or to the community—smallholders like those in part of Warwickshire, who can just manage by extremely hard labor to maintain themselves, or, like those in certain districts of Norfolk, who have let their holdings tumble down into corn and who produce no more and indeed less to the acre than do the large farmers who are their neighbors.

Before making any attempt to estimate the worth of these rival opinions it may be observed that the war has brought a large reinforcement of strength to the rank of the optimists. A contrast of personal experiences illustrates this fact. When in the early days of the war I felt it my duty to consult certain important county officials with the object of securing their support for schemes of intensive food production, I carried away from the conference one conclusion only: that the counties of England were of two kinds, those which were already doing much and were unable therefore to do more, and those which were doing little because there was no more to be done. In spite of this close application of the doctrine of Candide—that all is for the best in the best of all possible worlds—I was able to set up some sort of county horticultural organization, scrappy, amateurish, but enthusiastic, and the work done by that organization was on the average good; so much so indeed that when after the Armistice I sought to build up a permanent county horticultural organization I was met by a changed temper. The schemes which the staff of the Horticultural Division had elaborated as the result of experience during the war were received and adopted with a cordiality which I like to think was evoked no less by the excellence of the schemes themselves than by the promise of liberal financial assistance in their execution. Thus it came about that when the time arrived for me to hand over the controllership of Horticulture to my successor, almost every county had established a strong County Horticultural Committee, and the chief counties from the point of view of intensive cultivation had provided themselves with a staff competent to demonstrate not only to cottagers and allotment holders, but also to smallholders and commercial growers, the best methods of intensive cultivation. In the most important counties horticultural superintendents with knowledge of commer-

cial fruit-growing were being appointed, and demonstration fruit and market-garden plots, designed on lines laid down by Captain Wellington and his expert assistants, were in course of establishment. The detailed plans for these links in a national chain of demonstration and trial plots have been published, and any one who will study them will, I believe, recognize that they point the way to the successful development of a national system of intensive cultivation.

By means of these county stations the local cultivator may learn how to plant and maintain his fruit plantation and how to crop his vegetable quarters, what stock to run and what varieties to grow.

Farm stations—with the Research stations established previously by the Ministry; Long Ashton and East Malling for fruit investigations; the Lea Valley Growers' Association and Rothamstead for investigation of soil problems and pathology; the Imperial College of Science for research in plant physiology, together with a couple of stations, contemplated before the war, for local investigation of vegetable cultivation; an alliance with the Royal Horticultural Society's Research Station at Wisley, and with the John Innes Horticultural Institute for research in genetics; the Ormskirk Potato Trial Station; a Poultry Institute; and, most important of all from the point of view of education, the establishment at Cambridge of a School of Horticulture—constitute a horticultural organization which, if properly coordinated and—dare I say it?—directed, should prove of supreme value to all classes of intensive cultivators. To achieve that result, however, something more than a permissive attitude on the part of the ministry is required, and in completing the design of it I had hoped also to remain a part of that organization long enough to assist in securing its functioning as a living, plastic, resourceful, directive force—a horticultural cerebrum. Thus developed, it is my conviction that this instrument is capable of bringing Horticulture to a pitch of perfection undreamed of at the present time either in this country or elsewhere.

THE PROBLEMS OF ANTHROPOLOGY

By Professor KARL PEARSON

PRESIDENT OF THE ANTHROPOLOGICAL SECTION

ANTHROPOLOGY—the Understanding of Man—should be, if Pierre Charron were correct, the true science and the

true study of mankind.[1] We might anticipate that in our days —in this era of science—anthropology in its broadest sense would occupy the same exalted position that theology occupied in the Middle Ages. We should hail it "Queen of the Sciences," the crowning study of the academic curriculum. Why is it that we are Section H and not Section A? If the answer be given that such is the result of historic evolution, can we still be satisfied with the position that anthropology at present takes up in our British universities and in our learned societies? Have our universities, one and all, anthropological institutes well filled wth enthusiastic students, and are there brilliant professors and lecturers teaching them not only to understand man's past, but to use that knowledge to forward his future? Have we men trained during a long life of study and research to represent our science in the arena, or do we largely trust to dilettanti—to retired civil servants, to untrained travellers or colonial medical men for our knowledge, and to the anatomist, the surgeon, or the archeologist for our teaching? Needless to say, that for the study of man we require the better part of many sciences, we must draw for contributions on medicine, on zoology, on anatomy, on archeology, on folk-lore and travel-lore, nay, on history, psychology, geology, and many other branches of knowledge. But a hotch-potch of the facts of these sciences does not create anthropology. The true anthropologist is not the man who has merely a wide knowledge of the conclusions of other sciences, he is the man who grasps their bearing on mankind and throws light on the past and present factors of human evolution from that knowledge.

I am afraid I am a scientific heretic—an outcast from the true orthodox faith—I do not believe in science for its own sake. I believe only in science for man's sake. You will hear on every side the argument that it is not the aim of science to be utile, that you must pursue scientific studies for their own sake and not for the utility of the resulting discoveries. I think that there is a great deal of obscurity about this attitude, I will not say nonsense. I find the strongest supporters of "science for its own sake" use as the main argument for the pursuit of not immediately utile researches that these researches will be useful some day, that we can never be certain when they will turn out to be of advantage to mankind. Or, again, they will appeal to non-utile branches of science as providing a splendid intellectual

[1] "La vraye science et le vray estude de l'homme c'est l'Homme." Pierre Charron, *De la Sagesse*, Préface du Premier Livre, 1601. Pope, with his "The proper study of mankind is Man," 1733, was, as we might anticipate, only a plagiarist.

training—as if the provision of highly trained minds was not itself a social function of the greatest utility! In other words, the argument from utility is in both cases indirectly applied to justify the study of science for its own sake. In the old days the study of hyperspace—space of higher dimensions than that of which we have physical cognizance—used to be cited as an example of a non-utile scientific research. In view of the facts: (i) that our whole physical outlook on the universe—and with it I will add our whole philosophical and theological outlook—are taking new aspects under the theory of Einstein; and (ii) that study of the relative influences of nature and nurture in man can be reduced to the trigonometry of polyhedra in hyper-space—we see how idle it is to fence off any field of scientific investigation as non-utile.

Yet are we to defend the past of anthropology—and, in particular, of anthropometry—as the devotion of our science to an immediate non-utile which one day is going to be utile in a glorious and epoch-making manner, like the Clifford-Einstein suggestion of the curvature of our space? I fear we can take no such flattering unction to our souls. I fear that "the best is yet to be" can not be said of our multitudinous observations on "height-sitting" or on the censuses of eye or hair colors of our population. These things are dead almost from the day of their record. It is not only because the bulk of their recorders were untrained to observe and measure with scientific accuracy, it is not only because the records in nine out of ten cases omit the associated factors without which the record is valueless. It is because the progress of mankind in its present stage depends on characters wholly different from those which have so largely occupied the anthropologist's attention. Seizing the superficial and easy to observe, he has let slip the more subtle and elusive qualities on which progress, on which national fitness for this or that task essentially depends. The pulse-tracing, the reaction-time, the mental age of the men under his control are far more important to the commanding officer—nay, I will add, to the employer of labor—than any record of span, of head-measurement, or pigmentation categories. The psycho-physical and psycho-physiological characters are of far greater weight in the struggle of nations to-day than the superficial measurement of man's body. Physique, in the fullest sense, counts something still, but it is physique as measured by health, not by stature or eye-color. But character, strength of will, mental quickness count more, and if anthropometry is to be useful to the state it must turn from these rusty old weapons, these measurements of

stature and records of eye-color to more certain appreciation of bodily health and mental aptitude—to what we may term "vigorimetry" and to psychometry.

Some of you may be inclined to ask: And how do you know that these superficial size-, shape-, and pigment-characters are not closely associated with measurements of soundness of body and soundness of mind? The answer to this question is two-fold, and I must ask you to follow me for a moment into what appears a totally different subject. I refer to a "pure race." Some biologists apparently believe they can isolate a pure race, but in the case of man, I feel sure that purity of race is a merely relative term. For a given character one race is purer than a second, if the scientific measure of variation of that character is less than it is in the second. In loose wording, for we can not express ourselves accurately without mathematical symbols, that race is purer for which on the average the individuals are closer to type for the bulk of ascertainable characters than are the characters in a second race. But an absolutely pure race in man defies definition. The more isolated a group of men has remained, the longer it has lived under the same environment, and the more limited its habitat, the less variation from type it will exhibit, and we can legitimately speak of it as possessing greater purity. We, most of us, probably believe in a single origin of man. But as anthropologists we are inclined to speak as if at the dawn of history there were a number of pure races, each with definite physical and mental characteristics; if this were true, which I do not believe, it could only mean that up to that period there had been extreme isolation, extremely differentiated environment, and so marked differences in the direction and rate of mental and physical evolution. But what we know historically of folk-wanderings, folk-mixings, and folk-absorptions have undoubtedly been going on for hundreds of thousands of years, of which we know only a small historic fragment. Have we any real reason for supposing that "purity of race" existed up to the beginning of history, and that we have all got badly mixed up since?

Let us, however, grant that there were purer races at the beginning of history than we find to-day. Let us suppose a Nordic race with a certain stature, a given pigmentation, a given shape of head, and a given mentality. And again, we will suppose an Alpine race, differing markedly in type from the Nordic race. What happens if we cross members of the two races and proceed to a race of hybrids? A Mendelian would tell us that these characters are sorted out like cards from a pack in all sorts

of novel combinations. A Nordic mentality will be found with short stature and dark eyes. A tall but brachycephalic individual will combine Alpine mentality with blue eyes. Without accepting fully the Mendelian theory we can at least accept the result of mass observations, which show that the association between superficial physical measurements and mentality is of the slenderest kind. If you keep within one class, my own measurements show me that there is only the slightest relation between intelligence and the size and shape of the head. Pigmentation in this country seems to have little relation to the incidence of disease. Size and shape of head in man have been taken as a rough measure of size and shape of brain. They can not tell you more—perhaps not as much as brain-weight—and if brain-weight were closely associated with intelligence, then man should be at his intellectual prime in his teens.

Again, too often is this idea of close association of mentality and physique carried into the analysis of individuals within a human group, *i.e.*, of men belonging to one or another of the many races which have gone to build up our population. We talk as if it was our population which was mixed, and not our germplasm. We are accustomed to speak of a typical Englishman. For example, Charles Darwin; we think of his mind as a typical English mind, working in a typical English manner, yet when we come to study his pedigree we seek in vain for "purity of race." He is descended in four different lines from Irish kinglets; he is descended in as many lines from Scottish and Pictish kings. He has Manx blood. He claims descent in at least three lines from Alfred the Great, and so links up with Anglo-Saxon blood, but he links up also in several lines with Charlemagne and the Carlovingians. He sprang also from the Saxon Emperors of Germany, as well as from Barbarossa and the Hohenstaufens. He had Norwegian blood and much Norman blood. He had descent from the Duke of Bavaria, of Saxony, of Flanders, the Princes of Savoy, and the Kings of Italy. He had the blood in his veins of Franks, Alamans, Merovingians, Burgundians, and Longobards. He sprang in direct descent from the Hun rulers of Hungary and the Greek Emperors of Constantinople. If I recollect rightly, Ivan the Terrible provides a Russian link. There is probably not one of the races of Europe concerned in folk-wanderings which has not a share in the ancestry of Charles Darwin. If it has been possible in the case of one Englishman of this kind to show in a considerable number of lines how impure is his race, can we venture to assert that if the like knowledge were possible of attainment, we could

expect greater purity of blood in any of his countrymen? What we are able to show may occur by tracing an individual in historic times, wherever physical barriers did not isolate a limited section of mankind? If there ever was an association of definite mentality with physical characters, it would break down as soon as race mingled freely with race, as it has done in historic Europe. Isolation or a strong feeling against free inter-breeding—as in a color differentiation—could alone maintain a close association between physical and mental characters. Europe has never recovered from the general hybridization of the folk-wanderings, and it is only the cessation of wars of conquest and occupation, the spread of the conception of nationality and the reviving consciousness of race, which is providing the barriers which may eventually lead through isolation to a new linking-up of physical and mental characters.

In a population which consists of non-intermarrying castes, as in India, physique and external appearance may be a measure of the type of mentality. In the highly and recently hybridized nations of Europe there are really but few fragments of "pure races" left, and it is hopeless to believe that anthropometric measurements of the body or records of pigmentation are going to help us to a science of the psycho-physical characters of man which will be useful to the state. The modern state needs in its citizens vigor of mind and vigor of body, but these are not characters with which the anthropometry of the past has largely busied itself. In a certain sense the school medical officer and the medical officer of health are doing more state service of an anthropological character than the anthropologists themselves.

These doubts have come very forcibly to my notice during the last few years. What were the anthropologists as anthropologists doing during the war? Many of them were busy enough and doing valuable work because they were anatomists, or because they were surgeons, or perhaps even because they were mathematicians. But as anthropologists, what was their position? The whole period of the war produced the most difficult problems in folk-psychology. There were occasions innumerable where thousands of lives and most heavy expenditure of money might have been saved by a greater knowledge of what creates and what damps folk movements in the various races of the world. India, Egypt, Ireland, even our present relations with Italy and America, show only too painfully how difficult we find it to appreciate the psychology of other nations. We shall not surmount these difficulties until anthropologists take a wider view of the material they have to record and of the task

they have before them if they wish to be utile to the state. It is not the physical measurement of native races which is a fundamental feature of anthropometry to-day; it is the psychometry and what I have termed the vigorimetry of white- as well as of dark-skinned men that must become the main subjects of our study.

Some of you may consider that I am overlooking what has been contributed both in this country and elsewhere to the scienc of folk-psychology. I know at least that Wilhelm Wundt's[2] great work runs to ten volumes. But I also know that in its 5,452 pages there is not a single table of numerical measurements, not a single statement of the *quantitative* association between mental racial characters, nor, indeed, any attempt to show numerically the intensity of association between folk-mentality and folk customs and institutions. It is folk-psychology in the same stage of evolution as present-day sociology is in, or as individual psychology was in before the advent of experimental psychology and the correlational calculus. It is purely descriptive and verbal. I am not denying that many sciences must for a long period still remain in this condition, but at the same time I confess myself a firm disciple of Friar Roger Bacon[3] and of Leonardo da Vinci,[4] and believe that we can really know very little about a phenomenon until we can actually measure it and express its relations to other phenomena in quantitative form. Now you will doubtless suggest that sections of folk-psychology like Language, Religion, Law, Art—much that forms the substance of cultural anthropology—are incapable of quantitative treatment. I am not convinced that this standpoint is correct. Take only the first of these sections—*Language.* I am by no means certain that there is not a rich harvest to be reaped by the first man who can give unbroken time and study to the statistical analysis of language. Whether he start with roots or with words to investigate the degree of resemblance in languages of the same family, he is likely, before he has done, to learn a great deal about the relative closeness and order of evolution of cognate tongues, whether those tongues be Aryan or Sudanese. And the methods applicable in the case of language

[2] Its last volume also bears evidence of the non-judicial mind of the writer, who expresses strong opinions about recent events in the language of the party historian rather than the man of science.

[3] He who knows not Mathematics can not know any other science, and what is more can not discover his own ignorance or find its proper remedies.

[4] Nissuna humana investigatione si po dimandare vera scientia s'essa non passa per le matematiche dimonstratione.

will apply in the same manner to cultural habits and ideas. Strange as the notion may seem at first, there is a wide field in cultural anthropology for the use of those same methods which have revolutionized psychometric technique, to say nothing of their influence on osteometry.

The problems of cultural anthropology are subtle, but so indeed are the problems of anthropometry, and no instrument can be too fine if our analysis is to be final. The day is past when the arithmetic of the kindergarten sufficed for the physical anthropologist; the day is coming when mere verbal discussion will prove inadequate for the cultural anthropologist.

I do not say this merely in the controversial spirit. I say it because I want to find a remedy for the present state of affairs. I want to see the full recognition of anthropology as a leading science by the state. I want to see the recognition of anthropology by our manufacturers and commercial men, for it should be at least as important to them as chemistry or physics—the foundations of the anthropological institutes with their museums and professors in Hamburg and Frankfurt, have not yet found their parallels in commercial centers here. I want to see a fuller recognition of anthropology in our great scientific societies, both in their choice of members and in the memoirs published. If their doors are being opened to psychology under its new technique, may not anthropology also seek for fuller recognition?

It appears to me that if we are to place anthropology in its true position as the queen of the sciences, we must work shoulder to shoulder and work without intermittence in the following directions: anthropologists must not cease:

(i) To insist that our recorded material shall be such that it is at present or likely in the near future to be utile to the state, using the word "state" in its amplest sense.

(ii) To insist that there shall be institutes of anthropology, each with a full staff of qualified professors, whose whole energy and time shall be devoted to the teaching of and research in anthropology, ethnology and prehistory. At least three of our chief universities should be provided with such institutes.

(iii) To insist that our technique shall not consist in the mere statement of opinion on the facts observed, but shall follow, if possible with greater insight, the methods which are coming into use in epidemiology and psychology.

THE INDIVIDUAL CHILD AND METHODS OF TEACHING

By SIR ROBERT BLAIR

PRESIDENT OF THE EDUCATIONAL SECTION

IT is upon the latter problem, or group of problems, that experimental work has in the past been chiefly directed, and in the immediate future is likely to be concentrated with the most fruitful results. The recent advances in "individual psychology"—the youngest branch of that infant science—have greatly emphasized the need, and assisted the development, of individual teaching. The keynote of successful instruction is to adapt that instruction to the individual child. But before instruction can be so adapted, the needs and the capacities of the individual child must first be discovered.

Such discovery (as in all sciences) may proceed by two methods, by observation and by experiment.

1. The former method is in education the older. At one time, in the hands of Stanley Hall and his followers—the pioneers of the Child-Study movement—observation yielded fruitful results. And it is perhaps to be regretted that of late simple observation and description have been neglected for the more ambitious method of experimental tests. There is much that a vigilant teacher can do without using any special apparatus and without conducting any special experiment. Conscientious records of the behavior and responses of individual children, accurately described without any admixtures of inference or hypothesis, would lay broad foundations upon which subsequent investigators could build. The study of children's temperament and character, for example—factors which have not yet been accorded their due weight in education—must for the present proceed upon these simpler lines.

2. With experimental tests the progress made during the last decade has been enormous. The intelligence scale devised by Binet for the diagnosis of mental deficiency, the mental tests employed by the American army, the vocational tests now coming into use for the selection of employees—these have done much to familiarize, not school teachers and school doctors only, but also the general public, with the aims and possibilities of psychological measurement. More recently an endeavor has been made to assess directly the results of school instruction, and to record in quantitative terms the course of progress from year to year, by means of standardized tests for educational

attainments. In this country research committees of the British Association and of the Child-Study Society have already commenced the standardization of normal performances in such subjects as reading and arithmetic. In America attempts have been made to standardize even more elusive subjects, such as drawing, handwork, English composition, and the subjects of the curriculum of the secondary school.

This work of diagnosis has done much to foster individual and differential teaching—the adaptation of education to individual children, or at least to special groups and types. It has not only assisted the machinery of segregation—of selecting the mentally deficient child at one end of the scale and the scholarship child at the other end; but it has also provided a method for assessing the results of different teaching and methods as applied to these segregated groups. Progress has been most pronounced in the case of the sub-normal. The mentally defective are now taught in special schools, and receive an instruction of a specially adapted type. Some advance has more recently been made in differentiating the various grades and kinds of so-called deficiency; and in discriminating between the deficient and the merely backward and dull. With regard to the morally defective and delinquent little scientific work has been attempted in this country, with the sole exception of the new experiment initiated by the Birmingham justices. In the United States some twenty centers or clinics have been established for the psychological examination of exceptional children; and in England school medical officers and others have urged the need for "intermediate" classes or schools not only to accommodate backward and borderline cases and cases of limited or special defect (*e. g.*, "number-defect" and so-called "word-blindness") but also to act as clearing-houses.

In Germany and elsewhere special interest has been aroused in supernormal children. The few investigations already made show clearly that additional attention, expenditure, study, and provision will yield for the community a far richer return in the case of the super-normal than in the sub-normal.

At Harvard and elsewhere psychologists have for some time been elaborating psychological tests to select those who are best fitted for different types of vocation. The investigation is still only in its initial stages. But it is clear that if vocational guidance were based, in part at least, upon observations and records made at school, instead of being based upon the limited interests and knowledge of the child and his parents, then not only employers, but also employees, their work, and the community as

a whole, would profit. A large proportion of the vast wastage involved in the current system of indiscriminate engagement on probation would be saved.

The influence of sex, social status, and race upon individual differences in educational abilities has been studied upon a small scale. The differences are marked: and differences in sex and social status, when better understood, might well be taken into account both in diagnosing mental deficiency and in awarding scholarships. As a rule, however, those due to sex and race are smaller than is popularly supposed. How far these differences, and those associated with social status, are inborn and ineradicable, and how far they are due to differences in training and in tradition, can hardly be determined without a vast array of data.

The subjects taught and the methods of teaching have considerably changed during recent years. In the more progressive types of schools several broad tendencies may be discerned. All owe their acceptance in part to the results of scientific investigators.

1. Far less emphasis is now laid upon the *disciplinary value of subjects,* and upon subjects whose value is almost solely disciplinary. Following in the steps of a series of American investigators, Winch and Sleight in this country have shown very clearly that practise in one kind of activity produces improvements in other kinds of activities, only under very limited and special conditions. The whole conception of transfer of training is thus changed, or (some maintain) destroyed; and the earlier notion of education as the strengthening, through exercise, of certain general faculties has consequently been revolutionized. There is a tendency to select subjects and methods of teaching rather for their material than their general value.

2. Far less emphasis is now laid upon an advance according to strict *logical sequences* in teaching a given subject of the curriculum to children of successive ages. The steps and methods are being adapted rather to the natural capacities and interests of the child of each age. This genetic standpoint has received great help and encouragement from experimental psychology. Binet's own scale of intelligence was intended largely as a study in the mental development of the normal child. The developmental phases of particular characteristics (*e. g.*, children's ideals) and special characteristics of particular developmental phases (*e. g.*, adolescence) have been elaborately studied by Stanley Hall and his followers. Psychology, indeed, has done

much to emphasize the importance of the post-pubertal period—the school-leaving age, and the years that follow. Such studies have an obvious bearing upon the curriculum and methods for our new continuation schools. But it is, perhaps, in the revolutionary changes in the teaching methods of the infants' schools, changes that are already profoundly influencing the methods of the senior department, that the influence of scientific study has been most strongly at work.

3. Increasing emphasis is now being laid upon *mental and motor activities.* Early educational practise, like early psychology, was excessively intellectualistic. Recent child-study, however, has emphasized the importance on the motor and of the emotional aspects of the child's mental life. As a consequence, the theory and practise of education have assumed more of the pragmatic character which has characterized contemporary philosophy.

The progressive introduction of manual and practical subjects, both in and for themselves, and as aspects of other subjects, forms the most notable instance of this tendency. The educational process is assumed to start, not from the child's sensations (as nineteenth-century theory was so apt to maintain), but rather from his motor reactions to certain perceptual objects—objects of vital importance to him and to his species under primitive conditions, and therefore appealing to certain instinctive impulses. Further, the child's activities in the school should be, not indeed identical with, but continuous with, the activities of his subsequent profession or trade. Upon these grounds handicraft should now find a place in every school curriculum. It will be inserted both for its own sake, and for the sake of its connections with other subjects, whether they be subjects of school life, of after life, or of human life generally.

4. As a result of recent psychological work, more attention is now being paid to the *emotional, moral, and esthetic* activities. This is a second instance of the same reaction from excessive intellectualism. Education in this country has ever claimed to form character as well as to impart knowledge. Formerly, this aim characterized the public schools rather than the public elementary schools. Recently, however, much has been done to infuse into the latter something of the spirit of the public schools. The principle of self-government, for example, has been applied with success not only in certain elementary schools, but also in several colonies for juvenile delinquents. And, in the latter case, its success has been attributed by the initiators directly to the fact that it is a corollary of sound child-psychology.

Bearing closely upon the subject of moral and emotional training is the work of the psycho-analysts. Freud has shown that many forms of mental inefficiency in later life—both major (such as hysteria, neurosis, certain kinds of "shell-shock," etc.) and minor (such as lapses of memory, of action, slips of tongue and pen)—are traceable to the repression of emotional experiences in earlier life. The principles themselves may, perhaps, still be regarded as, in part, a matter of controversy. But the discoveries upon which they are based vividly illustrate the enormous importance of the natural instincts, interests, and activities, inherited by the child as part of his biological equipment; and, together with the work done by English psychologists such as Shand and McDougall upon the emotional basis of character, have already had a considerable influence upon educational theory in this country.

5. Increasing emphasis is now being laid upon *freedom* for individual effort and initiative. Here, again, the corollaries drawn from the psycho-analytic doctrines as to the dangers of repression are most suggestive. Already a better understanding of child-nature has led to the substitution of "internal" for "external" discipline; and the pre-determined routine demanded of entire classes is giving way to the growing recognition of the educational value of spontaneous efforts initiated by the individual, alone or in social cooperation with his fellows. In appealing for greater freedom still, the new psychology is in line with the more advanced educational experiments, such as the work done by Madame Montessori and the founders of the Little Commonwealth.

6. The *hygiene and technique of mental work* is itself being based upon scientific investigation. Of the numerous problems in the conditions and character of mental work generally, two deserve especial mention—fatigue, and the economy and technique of learning.

But of all the results of educational psychology, perhaps the most valuable is the slow but progressive inculcation of the whole teaching profession with a scientific spirit in their work, and a scientific attitude towards their pupils and their problems. Matter taught and teaching methods are no longer exclusively determined by mere tradition or mere opinion. They are being based more and more upon impartial observation, careful records, and statistical analysis—often assisted by laboratory technique—of the actual behavior of individual children.

EVOLUTION'S MOST ROMANTIC MOMENT

By Professor ROY L. MOODIE

UNIVERSITY OF ILLINOIS MEDICAL SCHOOL

THERE is a small stream in northern Illinois which, since the last great ice sheet retreated, has cut its unhurried way through some forty feet of glacial alluvium and has thus exposed in its present bed the shales and rocks of the old Coal Period which was the witness of Nature's most important moment. The old Indian name "Mazon" still clings to the stream and it has become famous the world over for the wonder and importance of the relics of ancient animal and plant life found along its banks. Locally the creek is held in contempt, by the grown-ups as a breeding place for mosquitoes, and by the small boys because it is nowhere deep enough for a good

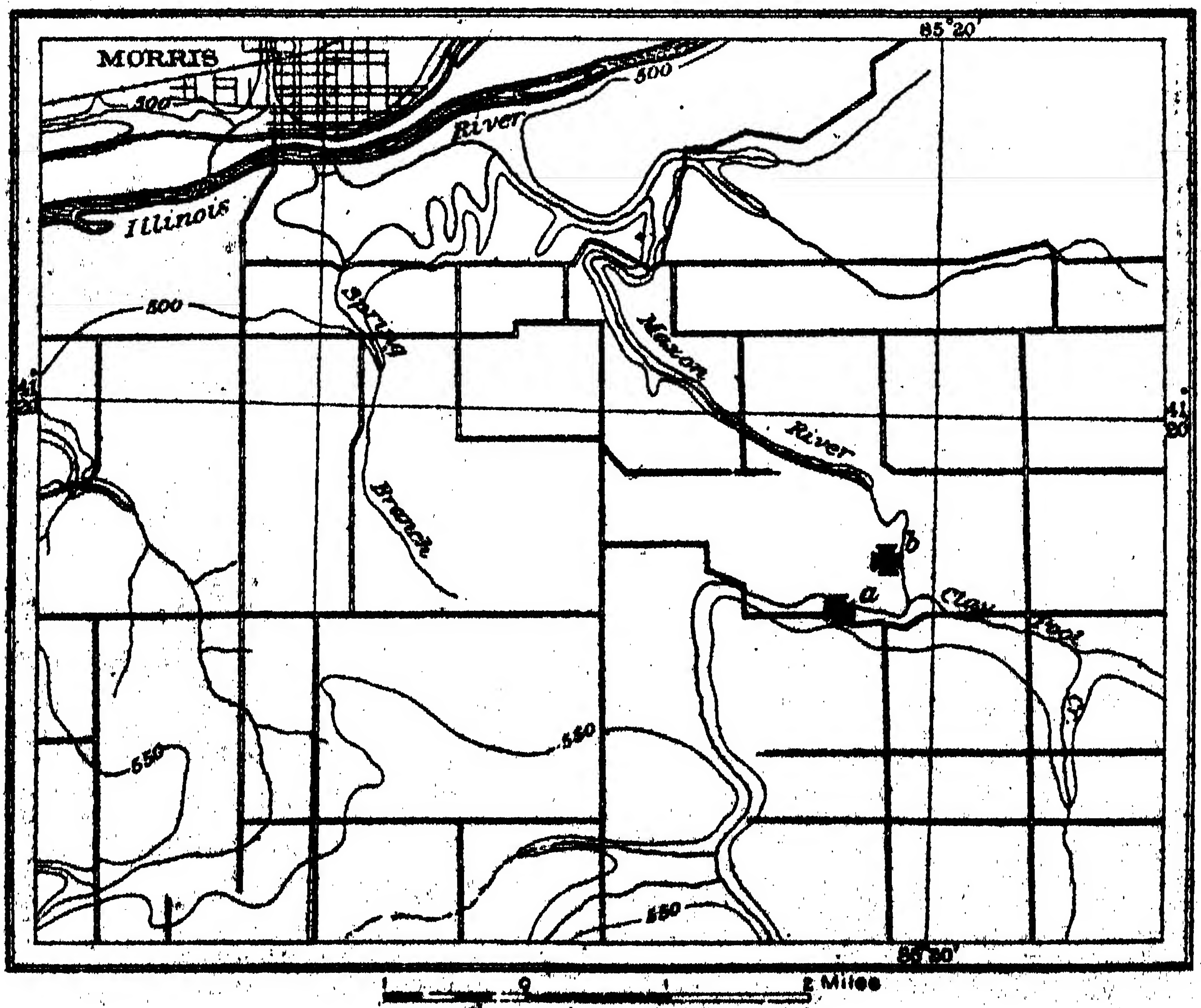


FIG. 1. TOPOGRAPHIC MAP OF THE MAZON CREEK, ILLINOIS, REGION, showing location of Fossil Beds.

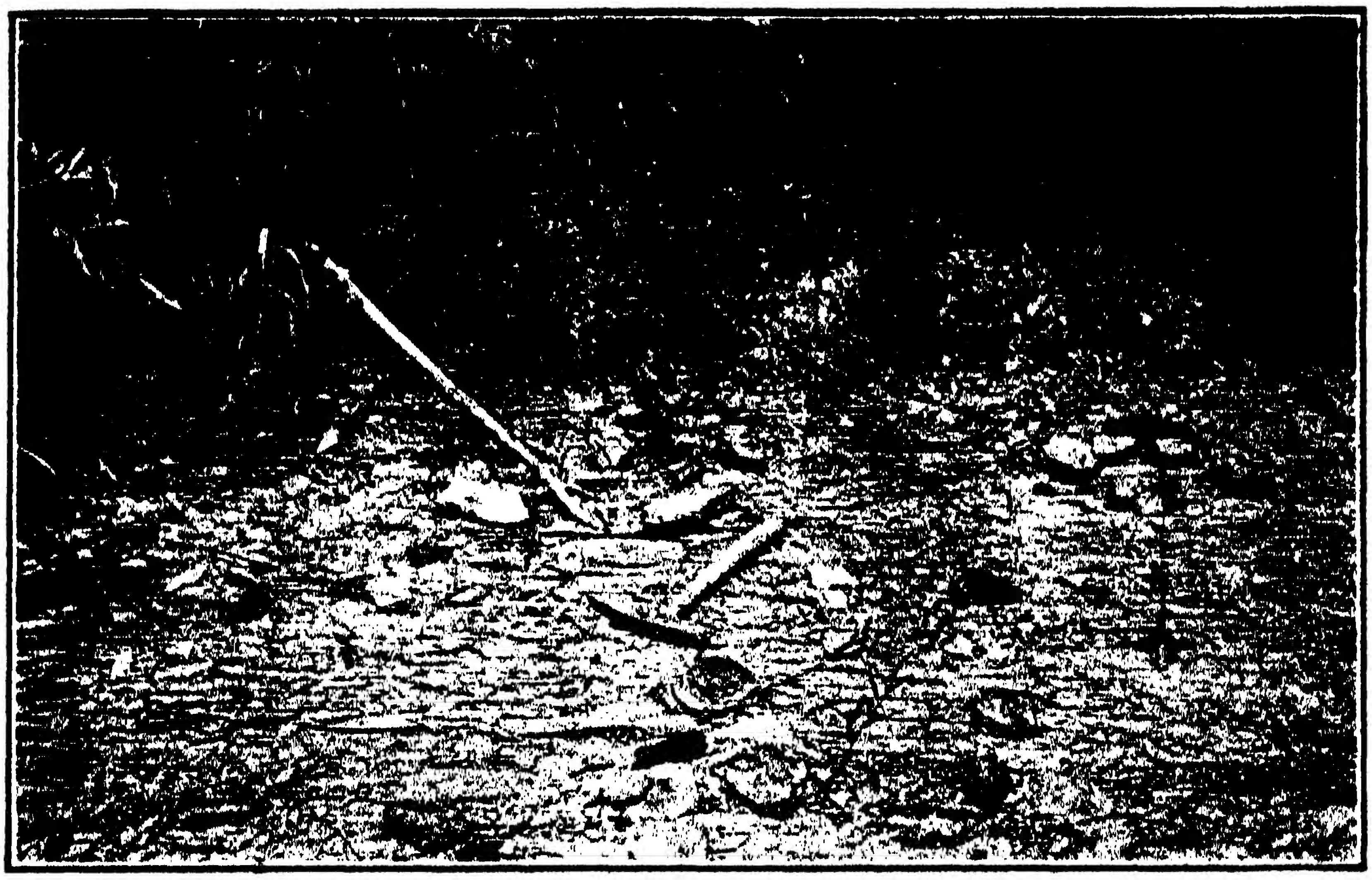


FIG. 2. A shale bed in the banks of Mazon Creek, from which the fossil-bearing nodules were washed out. One is just sliding down the bank at the head of the hammer. Nodules thus exposed are split by the action of the frost, or by a blow of the collector's hammer, thus revealing the enclosed fossil. Only twelve of these nodules have contained four-footed animals, in seventy-five years' collecting at this place.

swimming hole; fishing is almost unknown. The winding ripples, however, offer pleasant prospects to the casual visitor and its banks hold untold treasures for the student of ancient life.

The water has worn its placid way for centuries through several feet of grayish red shales, washing out an occasional rounded nodule, which, becoming exposed to the action of the frost, cracks and thus discloses its buried treasure of Paleozoic insect, centipede, spider, fish, leaf or, very, very rarely, *the remains of the first animal with legs,* which resembles so very closely our present mud-puppies. These small creatures are the oldest known land vertebrates and represent that most interesting and romantic phase when the animals which later resulted in the evolution of man were beginning to come out of the water and live a portion of their existence on land.

It is difficult for us, in these noisy times, to realize the stillness which pervaded all nature in this period when the animals were first considering an existence away from the water. It took eons of time for them to develop sufficient courage for a complete separation from their ancestral home. There were no voices of insect or bird in these later Paleozoic days, and the stillness was complete save for the wind, the rain and the thunder. The clouds doubtless sailed as quietly and as beauti-

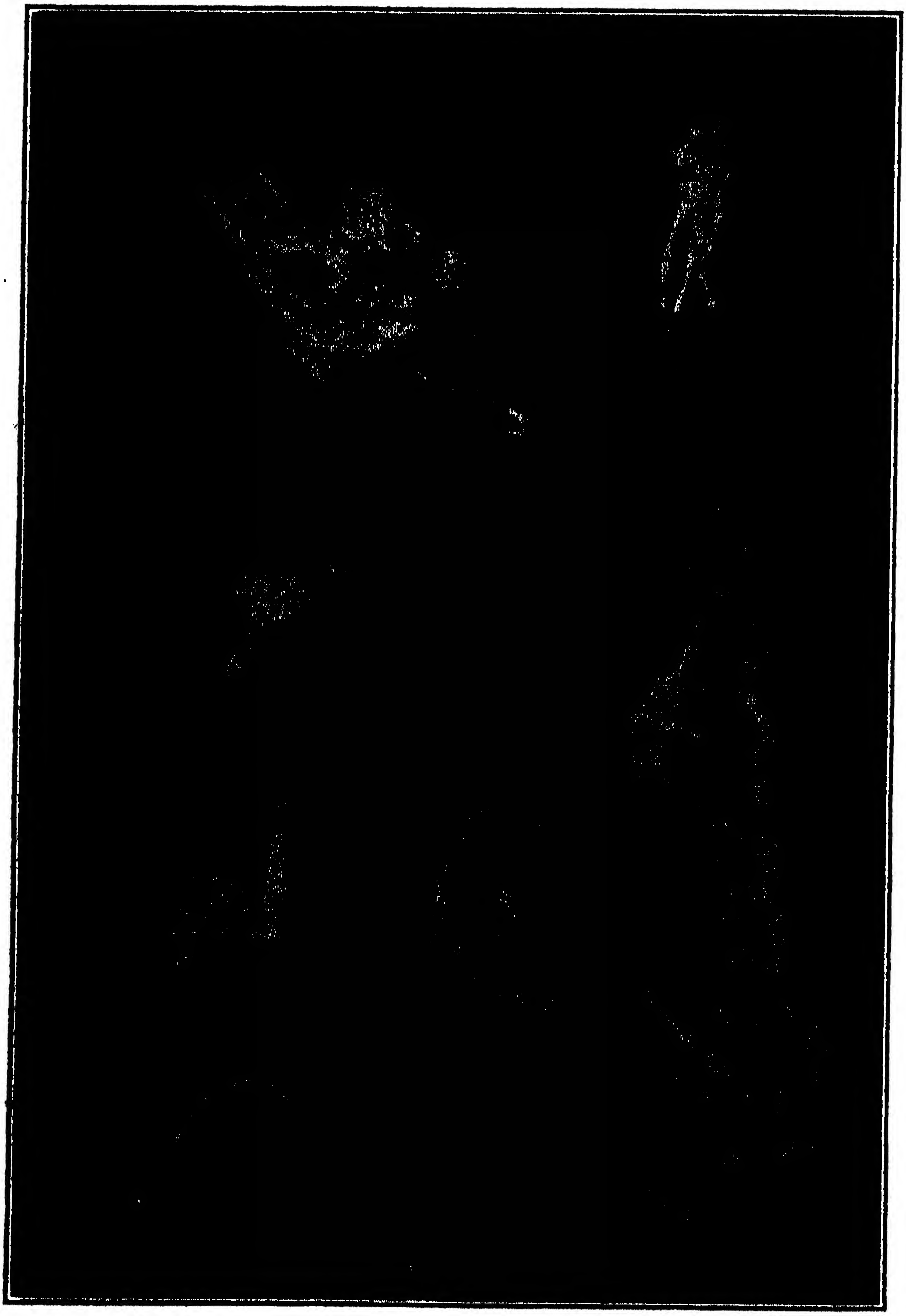


FIG. 3. Nature tried the experiment of evolving four-footed animals in several places at about the same time. Some of her experiments are preserved for us in the shape of fossils. The one here shown was found by Sir William Dawson in a petrified tree trunk, on the coast of Nova Scotia. This animal had lost the ability to swim and is thus a more highly developed stage of animal life than the ones found at Mazon Creek.

fully through the sky then as now. The sun shone as brightly, and the rain was as pure and refreshing. There were no grasses for the raindrops to glisten on and no trees, save only those of the fern type, where the wind might moan an unheard complaint. The little creatures of the shore, the highest type of animal of their day, neither heard nor spoke. They were made aware of the approach of danger in the water by the sense

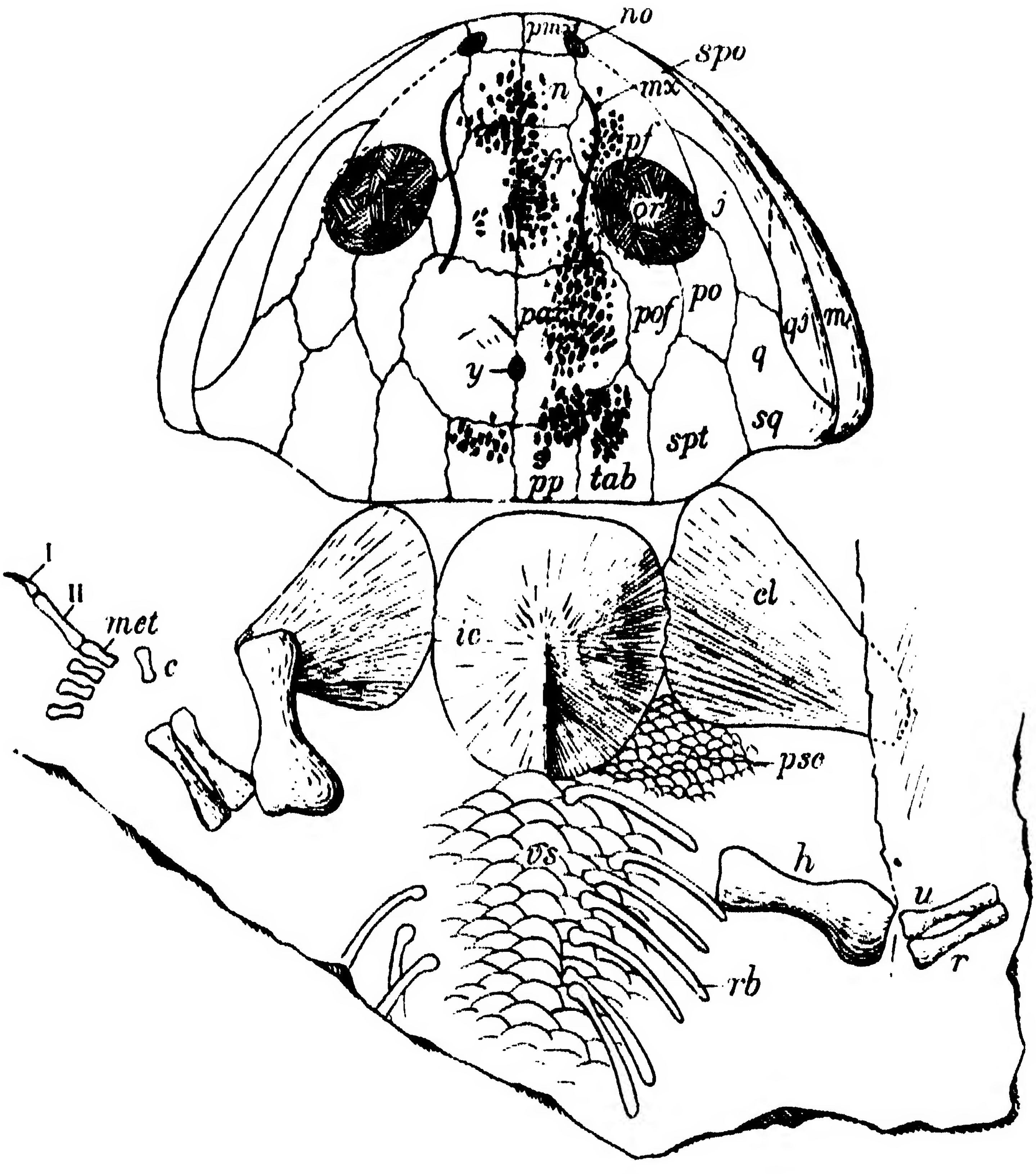


FIG. 4. At Linton, Ohio, in the Old Diamond mine, now long since abandoned, were discovered great numbers of the first animals with legs, though at a higher stage of development than those from Mazon Creek. The presence of scales on this fellow, who had a length of some 10 inches, do not indicate a fish ancestry, as might be supposed, but is rather an adaptation to aquatic life and similar structures are found even among many of the large reptiles of later times. The fossils of the coal are thus of the greatest importance in helping us to understand Evolution's most romantic moment.

organs in their skin, and on land they trusted to their large black eyes which set well exposed on top of their flat heads.

These little fellows, whose fossils we find on the banks of Mazon Creek, were timid adventurers and stayed close to the

shore of the old brackish bayou, the relics of which have come down to delight modern students in their attempt to unravel the story of the old world. None of them exceeded eight or at most ten inches in length, and they were often surpassed in size by even the centipedes which crawled through the swamps with them. But in potentialities of development these small knights of the Paleozoic surpassed anything the world had ever seen or will ever see again. They marked an important stage in this great progression of vertebrate life which has resulted in the development of the animate world as it is to-day. Had they not ventured on to the land, what to-day would have been the result? Would the world still be peopled only by denizens of the sea, or would the impulse for a higher life have come

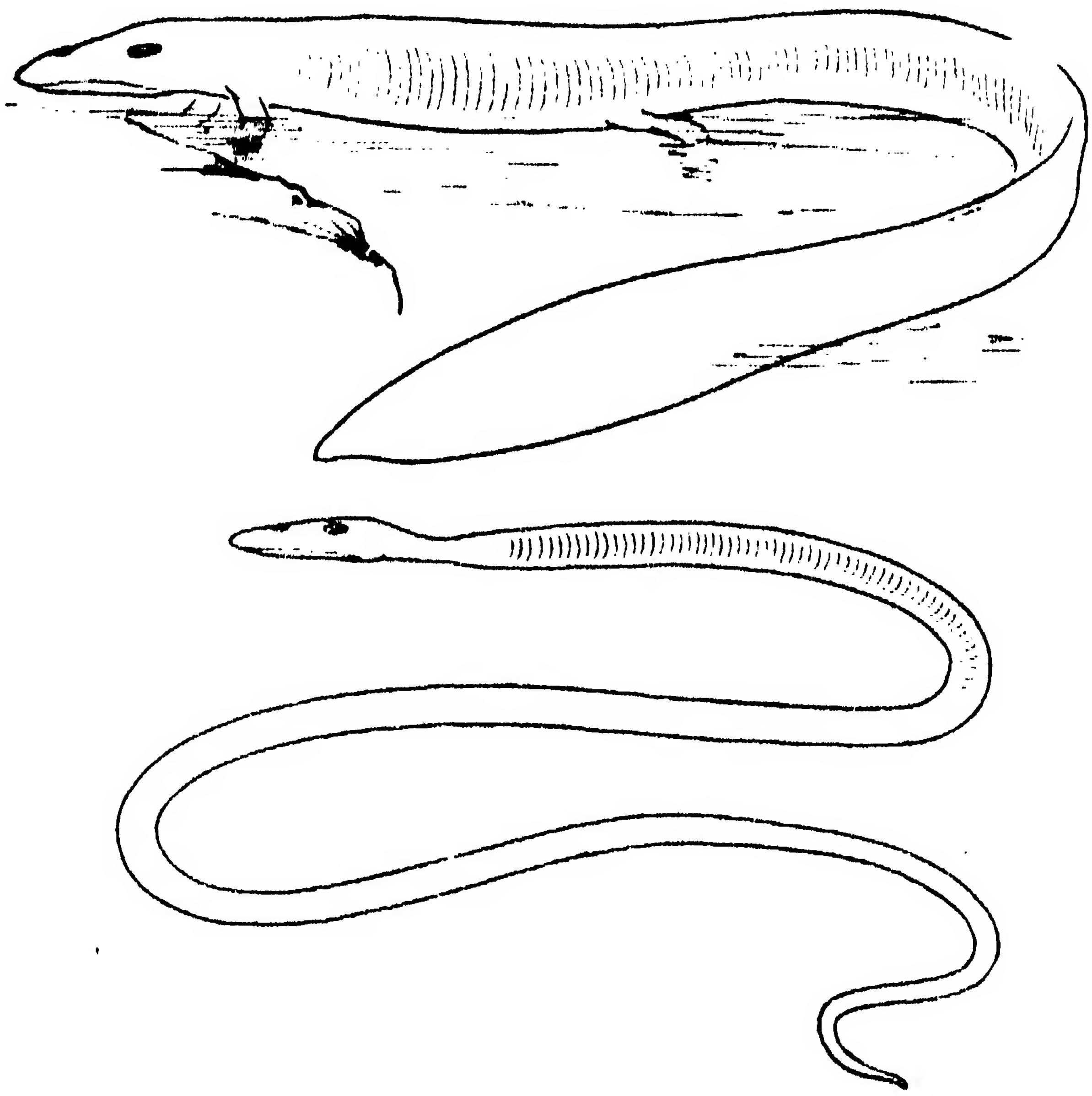


FIG. 5. At the same time, and in the same lake perhaps, with the development of four-legged animals which were found at Linton, Ohio, lived creatures which had either very weak legs, as shown in the upper figure, or none at all, as shown below. The latter form had lost all vestiges of both limbs and limb girdles.

at some later time? This impulse for a higher existence than one in the water, the desire to more freely, enjoy the sun and the earth, must have been very strongly implanted in the Paleozoic creatures, for shortly after, some 10,000,000 years later, the same experiment was tried in far remote places. Illinois, however, may claim the credit of being the present spot where millions of years ago the vertebrate animals, in their desire to develop into higher beings, first began that most romantic

movement in all evolution. Rather we should say that we see here, doubtless, the result of millions of years of preparation for, and a tendency toward, a stage which was in progress when the world was still quite young.

Evidently this experiment was a success, for we find the fossils of kindred forms in old tree stumps which have been washed out of the sea-cliffs of Nova Scotia. These animals, though still small, were extremely active. Their bodies were covered with hard scales. They had sharp claws on their feet, and could not swim, for they had progressed so far in the passage from water to land that they had all but forgotten the water, and when they fell into the rain water within an old hollow sigillarian stump, they drowned and were thus fossilized to tell the tale to-day. An intermediate stage is found in Ohio, where they were inhabitants of an old swampy lake in which they lived by thousands in various stages of development. Discoveries in other parts of the world add but little to our general conception of this parting point in evolution. While fossils from Africa, Europe, Australia and India delight our eye and stir our interest in their diversity of structure, none approaches so closely to that parting of the ways as the tiny creatures found on the banks of Mazon Creek, in Illinois. We, as human beings, are interested in their aspirations, for, had they not aspired to a life on land, many, many millions of years ago, evolution would have missed its most romantic moment and the world to-day would not be what it is. The development of our race might have been deferred many millenniums.

AN ANCIENT MOONFISH

By Dr. DAVID STARR JORDAN
STANFORD UNIVERSITY

ONE of the strangest of all fishes that swim the seas is the great moonfish or Opah, called in California "*Mariposa*" (*Lampris luna* Gmelin). It is a broad flat fish almost as deep as long, with flattened sides, small toothless mouth, and short tail with strong muscles at its base. It lives in the open seas, reaching a weight of four hundred pounds, and is likely to appear on any coast, though always very rarely. It has low fins, no scales and its body colors are a rich brocade of maroon and red with white spots of varying sizes and over all a bright sheen of silver. Its flesh is rich, tender and toothsome, but no person is likely to taste it more than once, as the fish seldom appears twice in the same place. Young specimens I have never seen and I would not know where to look for them, for the fish probably casts its spawn in the open sea.

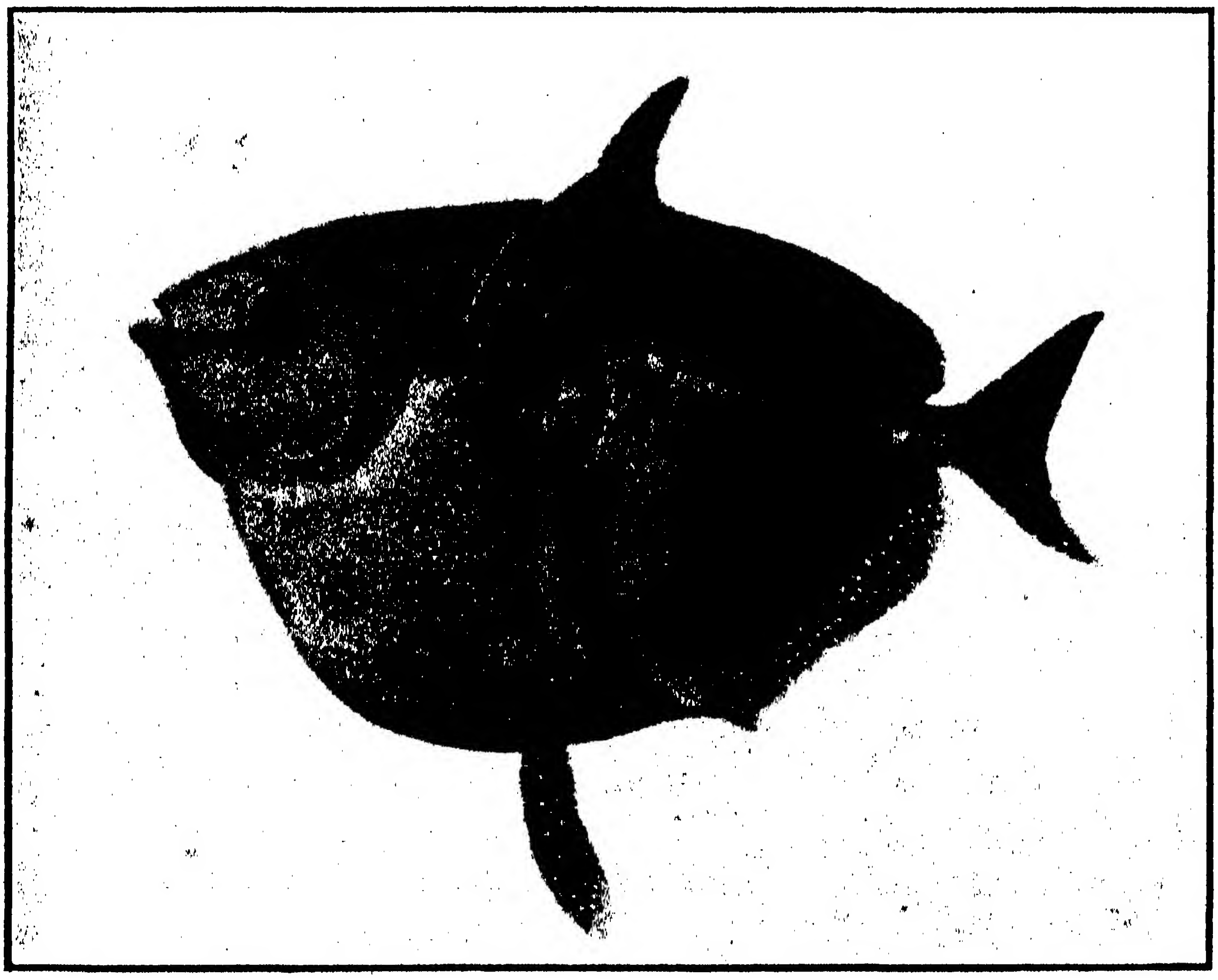


FIG. 1. Photograph of a cast by S. F. Denton of a *Lampris luna* weighing 100 lbs. taken at Honolulu. The triangular space between gill opening and ventral is all occupied by the shoulder girdle.

The one living species of *Lampris* is not related to any other existing fish, constituting an order (*Selenichthyes*) by itself. It bears some resemblance to the pomfret (*Brama*) and to other derivations of the mackerel tribe, but its likeness is superficial only, and not borne out by the skeleton. The bony framework

FIG. 2. Photograph of the shoulder girdle of a large example from Monterey, prepared by E. C. Starks.

shows many unique features, the most important being the extraordinary development of the shoulder girdle. The clavicle and hypocoracoid are excessively enlarged and separated by an interspace, the latter flattened and more or less fan-shaped downward, both bones being proportionately many times as large as in any other fish. The hypercoracoid, pierced by a large foramen, is also much enlarged and so placed that the actinosts or "wrist-bones" of the pectoral fin form a horizontal series, and the long oar-like fin can move only up and down. Behind the coracoids—the postclavicle extends as a long spear-shaped separate bone. Beside these features, the moonfish has very large and expanded pelvic bones, which support strong

ventral fins each with 15 long rays, a marked contrast to the one spine and five soft rays of most spiny-rayed fishes.

The extraordinary diatom beds at Lompoc, Santa Barbara County California, in which four square miles of a Miocene bay are covered to the depth of 1,400 feet with masses of pure diatoms, I have discussed elsewhere.[1] In these beds at one horizon occur untold millions of skeletons of a small herring (*Xyne grex*) while in the upper strata are many remains of predatory fish which have entered what was once a bottle-shaped bay in order to feed on herring. This is evident from the fact that one of the skeletons of a large mackerel has two herring skeletons in what was once its stomach.

FIG. 3. Skeleton of *Lampris zatima* taken in the Miocene Diatom beds at Lompoc, by E. J. Porteous. In this specimen a portion of the hypocoracoid of the left side appears detached under the other.

Among the relics of these predatory invaders is a very complete skeleton of a second species of moonfish, three feet long by about two broad. From *Lampris luna* it differs in the somewhat fewer vertebræ and fin rays, and in having the hypocoracoid broader, and less rapidly rounded off at its bottom.

[1] See "A Miocene Catastrophe," *Natural History*, XXI., No. 1, pp. 18–22, 1920.

Two smaller specimens, apparently of the same species, but lacking the head and shoulder girdle, had been previously found at Lompoc. To one of these Jordan and Gilbert (J. Z.) had given (in 1919) the name of *Diatomœca zatima.* With the complete skeleton, however, I see no characters by which *Diatomœca* can be separated as a genus from *Lampris.* The extinct moonfish of these Miocene Diatom beds may therefore stand as *Lampris zatima.* The specimen is one of great interest as showing the antiquity of one of the most singular of all living bony fishes, and incidentally with other associated forms, the relative age of the present fish fauna of California.

THE PROGRESS OF SCIENCE

THE POPULATION OF THE UNITED STATES IN 1920

THE Bureau of the Census has now made public the population of continental United States and of the separate states. According to the enumeration of the fourteenth census made this year, the population was 105,683,108, an increase of 13,710,842, or 14.9 per cent., since 1910. In 1910 the population of the outlying possessions, Alaska, Hawaii and Porto Rico, including those abroad on military and naval service, was 1,429,885. The results of the census for these possessions are not yet known and there are no correct figures for the Philippines. It is, however, estimated that the total population of the United States and its possessions is in the neighborhood of one hundred and eighteen million.

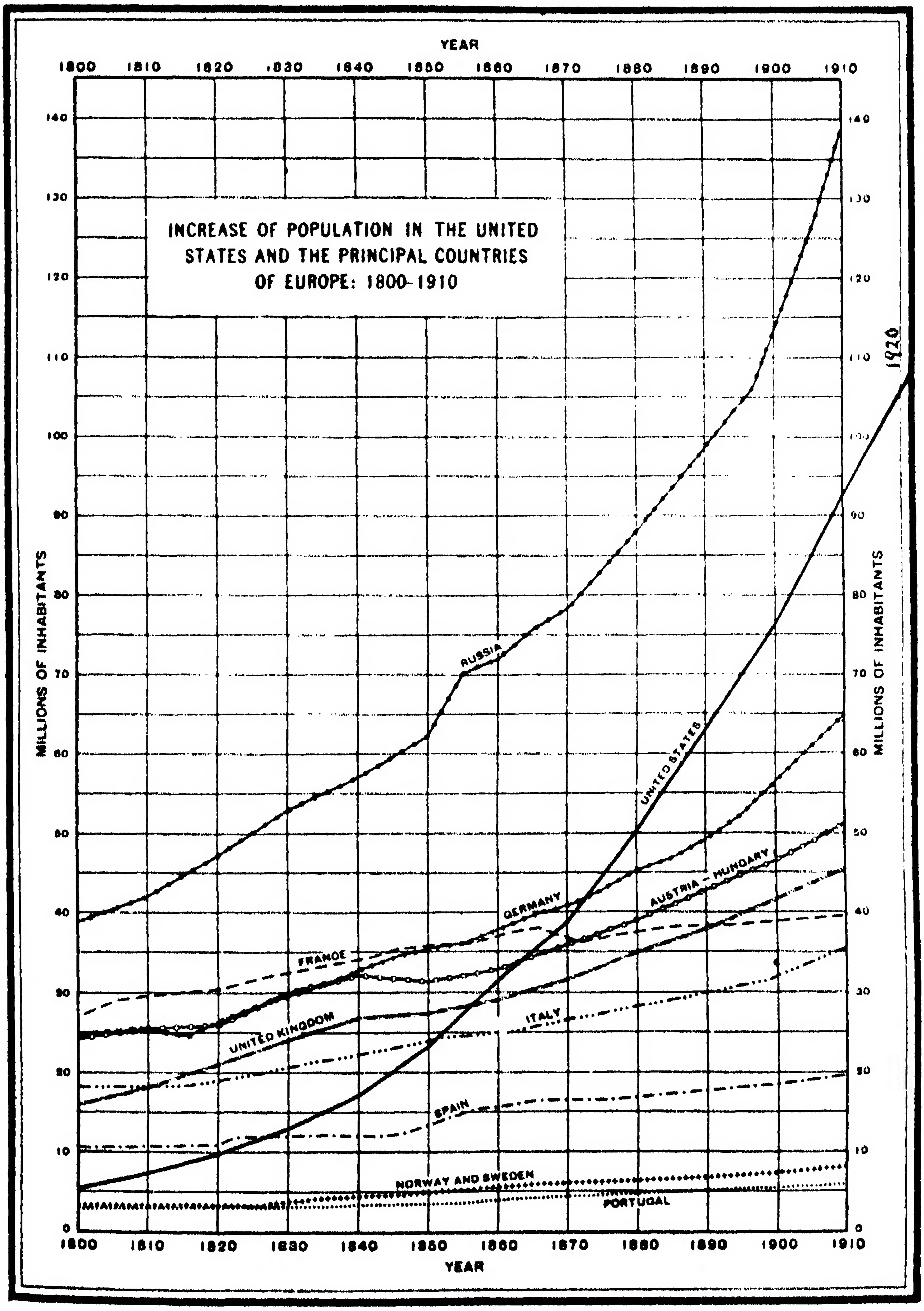
The growth of the country's population, exclusive of the outlying possessions, is set forth in this table:

Census year.	Population.	Increase.	P. c.
1920	105,683,108	13,710,842	14.9
1910	91,972,266	15,977,861	21.0
1900	75,994,575	13,046,861	20.7
1890	62,947,714	12,791,931	25.5
1880	50,155,783	11,597,412	30.1
1870	38,558,371	7,115,050	22.6
1860	31,443,321	8,251,445	35.6
1850	23,191,876	6,122,423	35.9
1840	17,069,453	4,203,433	32.7
1830	12,866,020	3,227,567	33.5
1820	9,638,453	2,398,572	33.1
1810	7,239,881	1,931,398	36.4
1800	5,308,483	1,379,269	35.1
1790	3,929,214	———	——

The fact that the increase in population was more than two million less in the last decade than in the one preceding is due to war conditions and especially to the cessation of immigration and the lack of the children that would have been born to immigrants. The actual fatal casualties of the war are a minor factor, perhaps not more than one tenth of the deaths from the epidemic of influenza, but a decreased birth rate in the native population due to war conditions may be as important as the failure of immigration.

The curves showing the increase in population in the United States seems to predict a continually increasing increment of growth. Indeed, Dr. H. S. Pritchett, then president of the Massachusetts Institute of Technology, fitted a parabolic curve to the data, and in an article published in THE POPULAR SCIENCE MONTHLY in 1900, predicted that the population of the country would be 114,416,000 in 1920, and over a billion a century hence. In a recent article in the *Proceedings* of the National Academy of Sciences Pearl and Reed point out that other curves fit the figures equally well, and are more nearly in accord with reasonable expectation. They propose a curve taking into account the food supply in a limited area, according to which the period of most rapid growth ended in 1914, and the maximum population of the country will be about two hundred million.

There seems, however, to be no reason why the increase in population should follow a course that can be represented by any mathematical formula. The rate of increase in the United States has been largely due to immigration, in Russia to the large birth rate of an agricultural population with a decreasing death rate, in Germany to developments that supported an industrial population by commerce. As shown on the diagram, the curves for the three

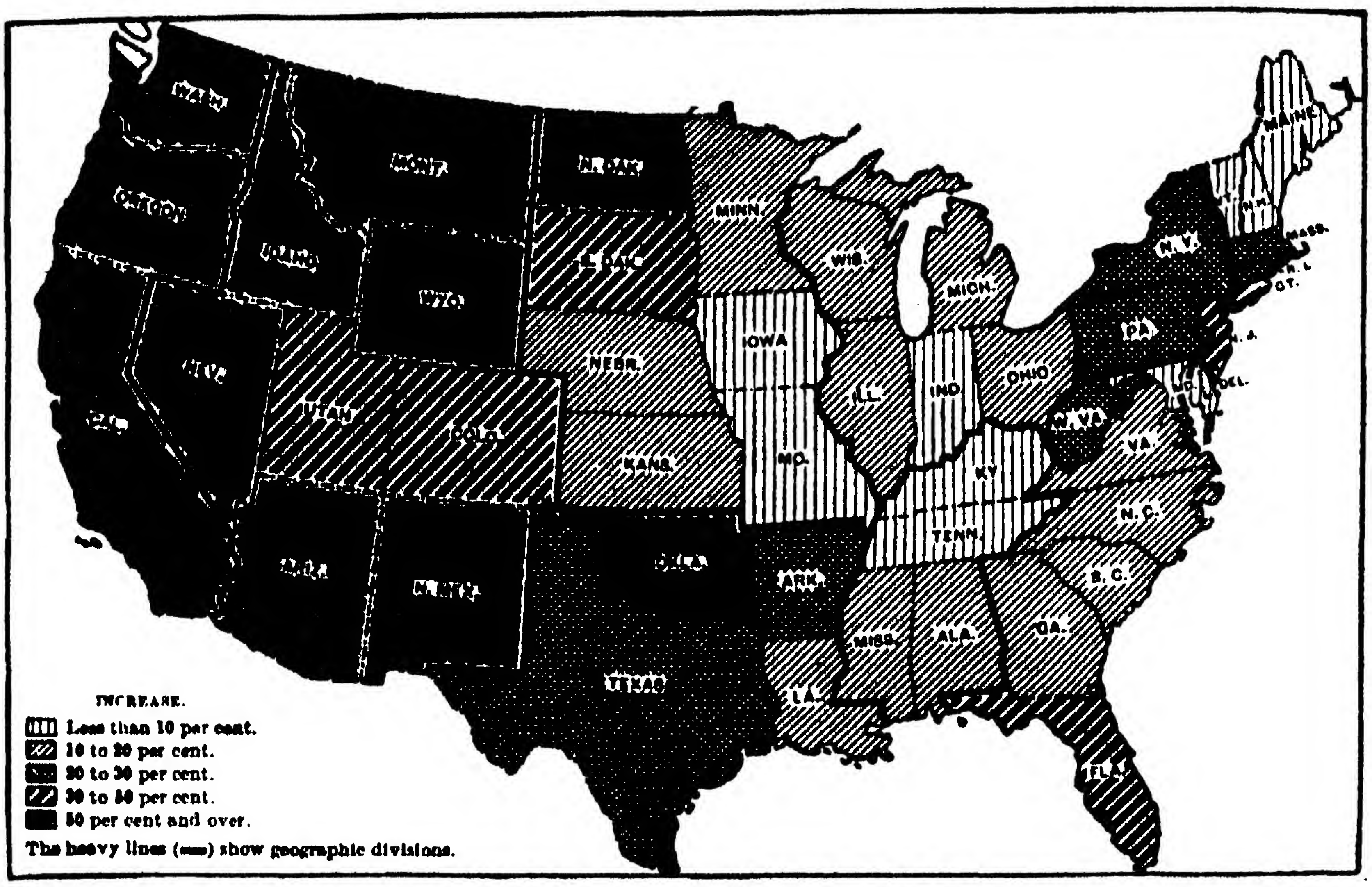


INCREASE OF POPULATION OF THE UNITED STATES AND COUNTRIES OF EUROPE

nations follow a somewhat similar course of increasing increments of population that can be represented by a parabolic equation. The catastrophe of war has altered the course of the curves to an extent unknown except in the United States.

But apart from war, pestilence and famine, there are new causes altering the situation. Two of dominating importance have been the applications of science to agriculture, industry and commerce, enabling the civilized nations to support a popu-

PER CENT OF INCREASE IN TOTAL POPULATION, BY STATES: 1900–1910



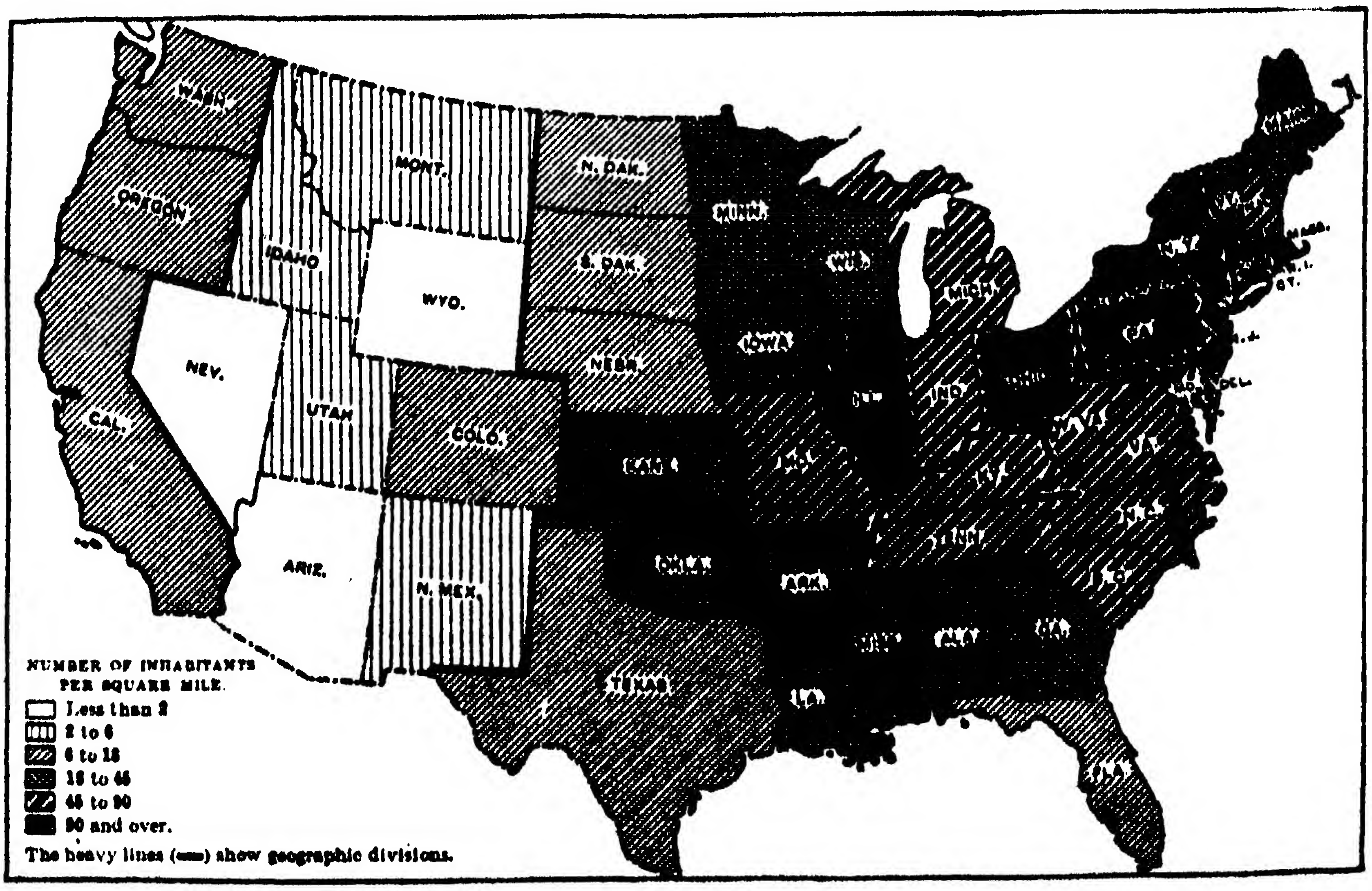
INCREASE OF POPULATION BY STATES. POPULATION PER SQUARE MILE.

lation perhaps four times as great as would otherwise have been possible, and the voluntary limitation of births. The former of these is responsible for the curves of population since 1790. The latter will have an effect during the present century that no equation based on the past can predict.

THE DISTRIBUTION OF THE POPULATION

THE accompanying diagrams show the increase in population by states

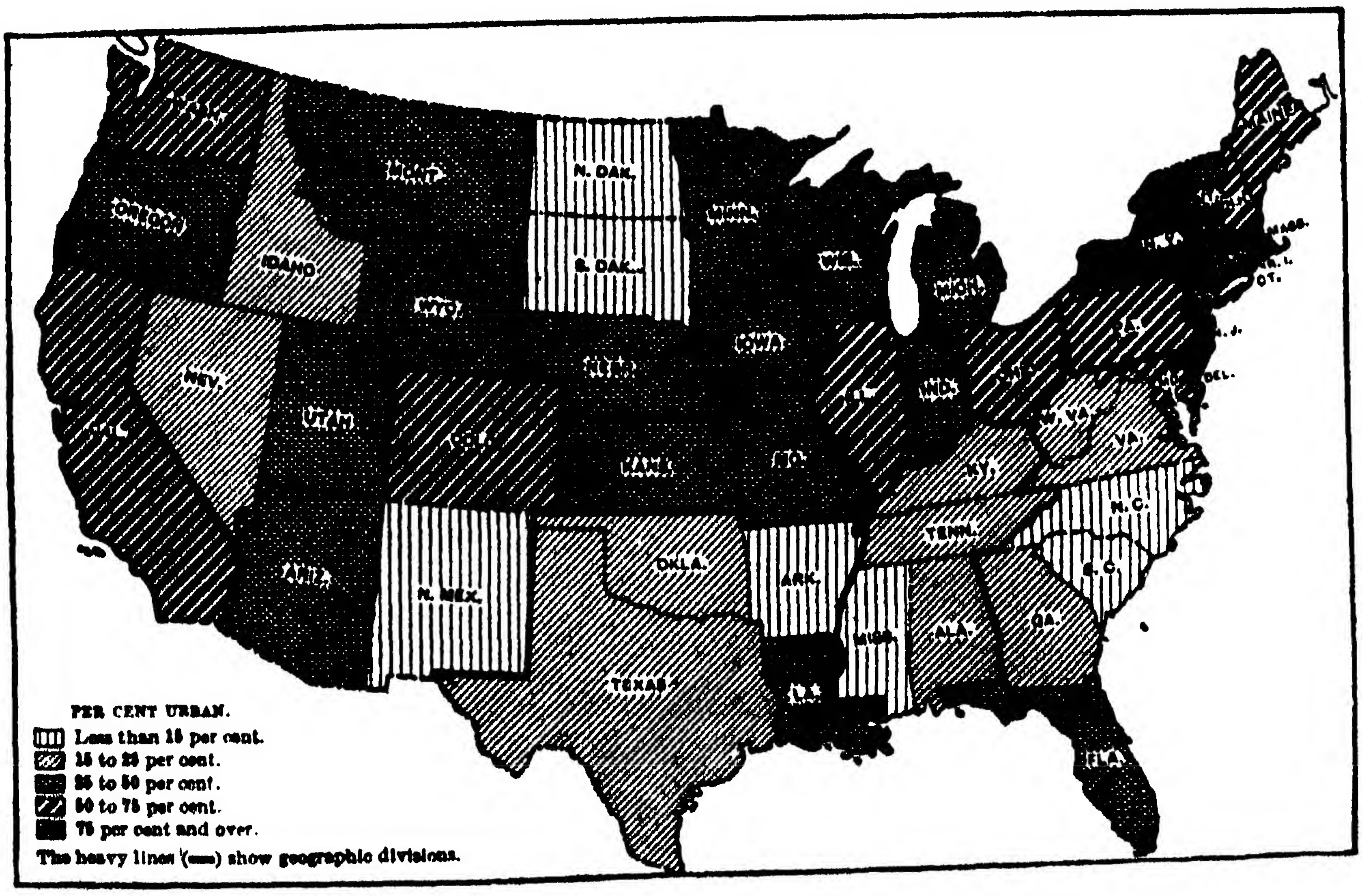
POPULATION PER SQUARE MILE, BY STATES: 1910



according to the census of 1910, the population per square mile and the per cent. of urban population. The population of the several states in 1920 and in 1910 and the per cent. of increase are shown in the figures that follow:

State	Population 1920	1910	P. c. of Gain
United States	105,683,108	91,972,266	14.9
Alabama	2,347,295	2,138,093	9.8
Arizona	333,273	204,354	63.1
Arkansas	1,750,995	1,574,449	11.2
California ...	3,426,536	2,377,549	44.1
Colorado	939,376	799,024	17.6
Connecticut ..	1,380,585	1,114,756	23.8
Missouri	3,403,547	3,293,335	3.3
Montana	547,593	376,053	45.6
Nebraska ...	1,295,502	1,192,214	8.7
Nevada	77,407	81,875	5.5
N. Hampshire	443,083	430,572	2.9
New Jersey ..	3,155,374	2,537,167	24.4
New Mexico .	360,247	327,301	10.1
New York ...	10,384,144	9,113,614	13.9
North Carolina	2,556,486	2,206,287	15.9
North Dakota.	645,730	577,056	11.9
Ohio	5,759,368	4,767,121	20.8
Oklahoma ...	2,027,564	1,657,155	22.4
Oregon	783,389	672,765	16.4
Pennsylvania .	8,720,159	7,665,111	13.8
Rhode Island.	604,397	542,610	11.4
South Carolina	1,683,662	1,515,400	11.1
South Dakota.	635,839	583,888	8.9
Tennessee ...	2,337,459	2,184,789	7.0

PER CENT URBAN IN TOTAL POPULATION, BY STATES: 1910



PER CENT. OF URBAN POPULATION.

Delaware ...	223,003	202,322	10.2
Dist. of Col...	437,571	331,069	32.2
Florida	966,296	752,619	28.4
Georgia	2,894,683	2,609,121	10.9
Idaho	431,826	325,594	32.6
Illinois	6,485,098	5,638,591	15.0
Indiana	2,930,544	2,700,876	8.5
Iowa	2,403,630	2,224,771	8.0
Kansas	1,769,257	1,690,945	4.6
Kentucky ...	2,416,013	2,289,905	5.5
Louisiana ...	1,797,798	1,656,388	8.5
Maine	768,014	742,371	3.5
Maryland ...	1,449,610	1,295,346	11.9
Massachusetts	3,852,356	3,366,416	14.4
Michigan ...	3,667,222	2,810,173	30.5
Minnesota ...	2,386,371	2,075,708	15.0
Mississippi ..	1,789,384	1,797,114	0.4
Texas	4,661,027	3,896,542	19.6
Utah	449,446	373,351	20.4
Vermont	352,421	355,956	1.0
Virginia	2,309,361	2,061,612	11.9
Washington .	1,356,316	1,141,990	18.8
W. Virginia .	1,463,610	1,221,119	19.9
Wisconsin ...	2,631,839	2,333,860	12.8
Wyoming	194,402	145,965	33.2

The largest relative increase has been the gain of 63.1 per cent. in Arizona, followed by Montana, California and Wyoming. For three States, Mississippi, Nevada and Vermont, there have been small de-

creases in population, the largest being for Nevada, 5.5 per cent.

The director of the census has issued a statement according to which the figures of the present census show that the trend of population from the country to the city has become greatly accentuated since 1910 and that, for the first time in the country's history, more than half the entire population is now living in urban territory as defined by the Census Bureau. That is to say, of the 105,683,108 persons enumerated in the fourteenth census preliminary tabulations show that 54,816,209, or 51.9 per cent., are living in incorporated places of 2,500 inhabitants or more, and 50,866,899, or 48.1 per cent., in rural territory.

At the census of 1910 the corresponding percentages were 46.3 and 53.7, respectively, showing a loss of 5.6 per cent. in the proportion for the population living in rural territory. To show more clearly the change in the proportion of the population living in rural territory now as compared with ten years ago the rural population can be divided into two classes, namely, 9,864,196, or 9.3 per cent. of the total population, living in incorporated places of less than 2,500 inhabitants, and 41,002,703, or 38.8 per cent. of the total population, living in what may be called purely country districts. At the census of 1910 the population living in incorporated places of less than 2,500 inhabitants formed 8.8 per cent., while the population living in purely country districts formed 44.8 per cent. of the total population.

The increase since 1910 in the population as a whole, as before stated, was 14.9 per cent., but during the decade there has been an increase in that portion of the population living in urban territory of 12,192,826, or 28.6 per cent., and in that portion living in rural territory of 1,518,016, or only 3.1 per cent.; and if the comparison is extended to cover the two classes of rural territory, it appears that that portion living in incorporated places of less than 2,500 inhabitants show an increase of 1,745,371, or 21.5 per cent., whereas that portion living in purely country districts shows an actual decrease of 227,355.

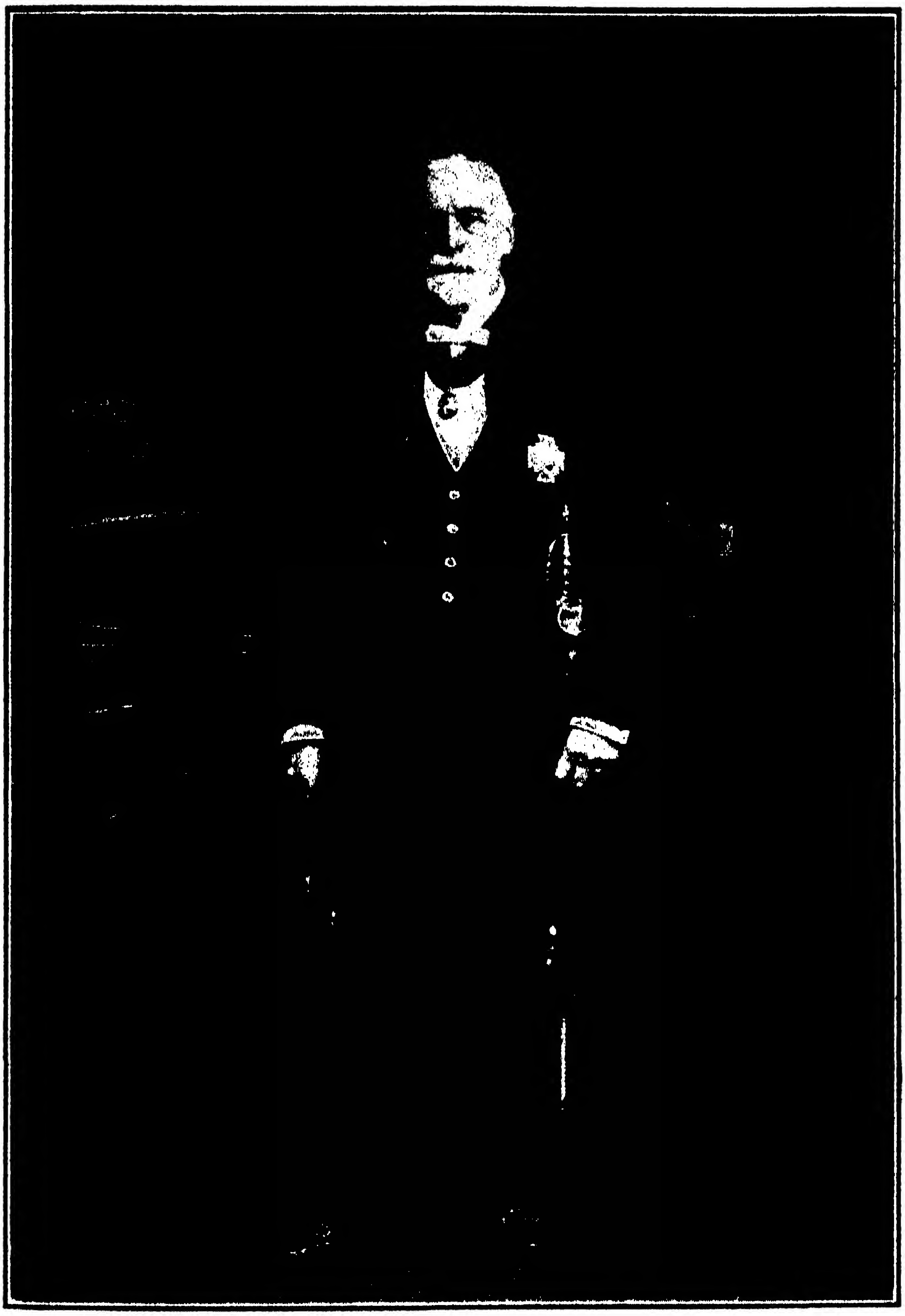
TRIBUTE TO THE MEMORY OF JAMES WILSON

SYMPATHY at the death of former Secretary of Agriculture James Wilson was sent to his family in the form of a resolution adopted at a meeting of the chiefs of the various bureaus of the United States Department of Agriculture. Tribute was paid to the former head of the department for "his patriotic devotion to the interests of all the people, his broad vision, and his practical wisdom." As a token of respect the flags on all department buildings were placed at halfstaff, and remained so until after the funeral, which took place at Traer, Iowa.

Because of the time of the funeral, the department was unable to send representatives from Washington. The department, however, designated Dr. Henry C. Taylor, Chief of the Office of Farm Management, who was in the Middle West; Frank S. Pinney, Federal agricultural statistician at Des Moines; and R. E. Doolittle, Chief of the Central Food and Drug Inspection District at Chicago, to represent it at the funeral.

A floral tribute was sent by officials and employees of the department as a token of esteem for their former chief. The message of sympathy sent the family of Mr. Wilson followed a similar personal message sent by Secretary of Agriculture Meredith. The resolution of the bureau chiefs, forwarded by Assistant Secretary of Agriculture Ball, read:

The members of the Department of Agriculture, feeling deeply the



SIR CLIFFORD ALLBUTT.

Regius Professor of Physics in the University of Cambridge, president of the British Medical Association for the meeting held during the summer at Cambridge. A portrait of Sir Clifford by Sir William Orpen was at the time presented to him by the British medical profession.

loss of their former secretary, James Wilson, of Iowa, desire to express their sympathy with his family and their appreciation of his great services to the United States as Dean of Agriculture, member of Congress, and Secretary of Agriculture. His patriotic devotion to the interests of all the people, his broad vision, and his practical wisdom place him high among those who have deserved well of their country. Beloved as a friend, admired and respected as an official, his example as a man and a statesman is one to which all Americans may turn for inspiration and emulation: Therefore be it

Resolved, That in the death of James Wilson American agriculture has lost one of its greatest exponents and American citizenship one of its finest exemplars.

In token of respect the flags on all department buildings will be placed at half-mast, and a copy of this resolution will be sent to the family.

SCIENTIFIC ITEMS

We record with regret the deaths of Eric Doolittle, professor of astronomy in the University of Pennsylvania; Samuel Sheldon, professor of physics and electrical engineering at the Brooklyn Polytechnic Institute; Frederick Henry Gerrish, emeritus professor of surgery in the Medical School of the University of Maine; Armand Gautier, professor of biological chemistry in the Paris School of Medicine, and Karl Hermann Struve, director of the Berlin Observatory.

Dr. Leo S. Rowe, assistant secretary of the treasury and formerly professor of political science in the University of Pennsylvania, has assumed the directorship of the Pan-American Union at Washington, succeeding Dr. John Barrett, who has retired after fifteen years as head of the union. Sir F. W. Dyson, astronomer royal, Greenwich, has been elected an honorary member of the American Astronomical Society.

American nations, as well as Great Britain, Spain and Portugal, are to be formally invited to participate in the national festivities in November and December in commemoration of the four hundredth anniversary of the discovery of the Straits of Magellan. The festivities will center principally in Santiago and Punta Arenas, the latter the world's southernmost city, where the occasion will be marked by inauguration of important public works, including port improvements, lighthouses in Smith Channel, a highway between Punta Arenas and Natales on the South Atlantic coast and laying of a cornerstone of the Punta Arenas University. It is expected the foreign delegations will visit the straits in December, when warships of the Chilean navy will be assembled there. It was through these waters that Ferdinand Magellan, the Portuguese explorer, first passed in November, 1520.

THE SCIENTIFIC MONTHLY

DECEMBER, 1920

AT TIMBER-LINE IN THE LAND OF TAHOSA[1]

AN INTRODUCTION TO THE AGED GNOMES OF AN ALPINE ELFIN-WOOD

By RAYMOND J. POOL

PROFESSOR OF BOTANY, THE UNIVERSITY OF NEBRASKA

FROM a land of beetling crags and tumbling cascades, from a land of snowy summits and booming storms, from a land of glacier-driven valleys and verdant forests, from a land of spire-crowned spruces and quivering aspen trees, from the land of Tahosa comes my story. Tahosa, the land whence myriads of sparkling mountain fonts bequeath perpetual laughter to the slender threads which, converging, evolve the mighty Colorado and start it on its silvery, winding way through the mighty chasm; a chasm sunken by the slowly laboring mechanic of the ages into the layered floor of that great plateau where the soft warm tones of the setting sun reflected from rugged cliff and treacherous talus mingle with the twilight haze of the great southwest.

THE LAND OF TAHOSA

Tahosa is the name that we would now use for one of our great mountain states had the request of those who petitioned for statehood been granted. "Dwellers of the mountain-tops," the name is particularly fitting for the state called Colorado, for that state claims a thousand mighty mountains which raise their rugged summits to altitudes exceeding two miles above the level of the far-off sea. There are in Colorado literally scores of mountain peaks which mount toward the sky beyond 13,000 feet, and many of these even exceed 14,000 feet. So Tahosa (if we may use the name) is indeed a place of mountain tops.

[1] Illustrations from Photographs by the Author.

THE STORY OF A TRAGIC PAST IS MIRRORED IN THE MANGLED FORMS OF THE STORM-TOSSED AND TIME-WORN TREES WHICH STAND FORTH AS THE OUTPOSTS OF THE ALPINE FOREST PRIMEVAL.

At Timber-line

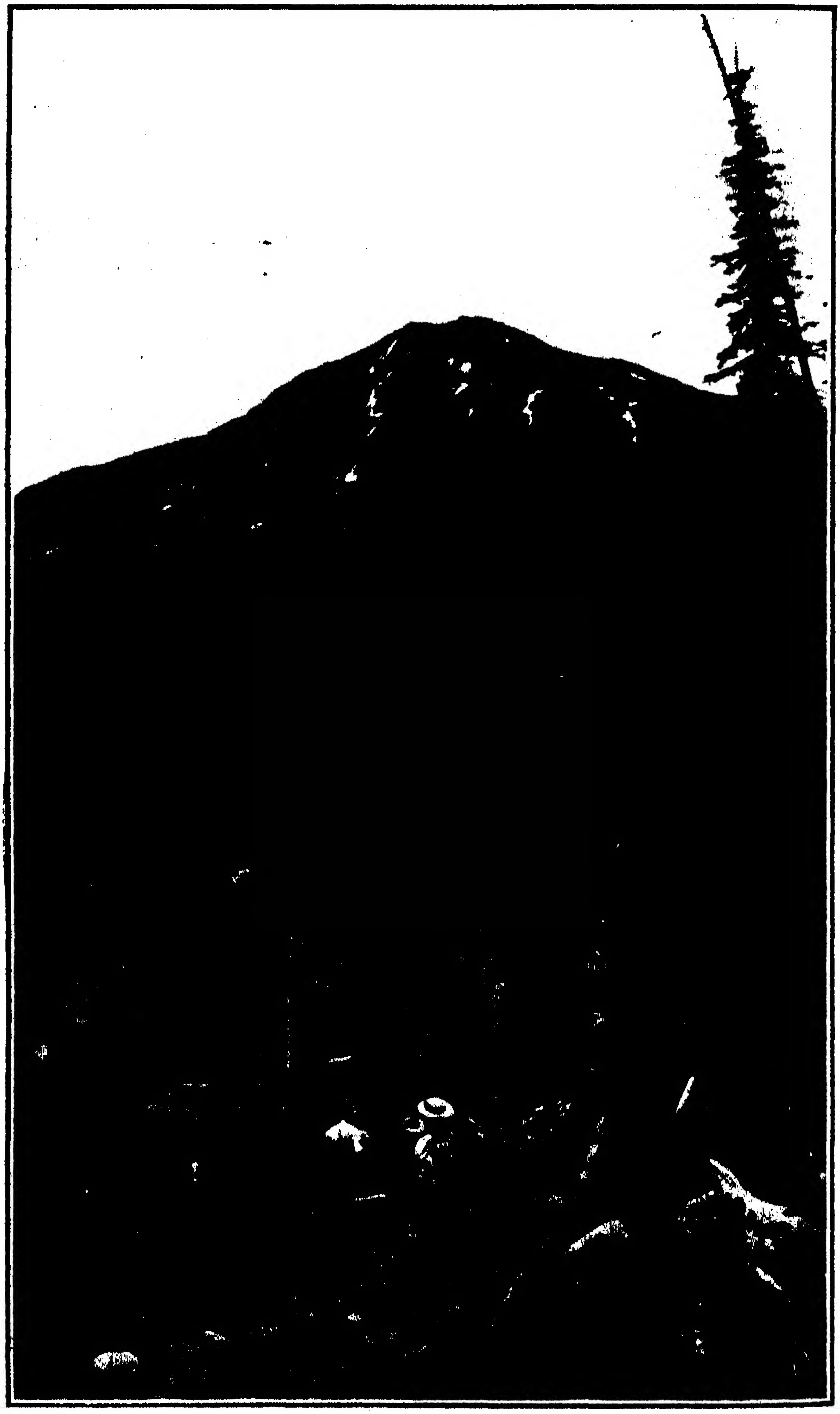
To one who loves the thrill of the dynamic landscapes of nature, and who delights in the muscular pull necessary "to go up to the sky in the mountains" there is no place at once so alluring and so thought-compelling as timber-line. The ever-changing forms and phenomena about one lure the climber to greater and greater heights. The rarefied atmosphere and an accelerated pulse draw and drive him upward.

At timber-line one beholds the upturned faces of the ancient past mirrored in the glacier-polished valleys and upon the lichen-covered cliffs of a granite cirque or in the jumbled, boulder-strewn moraine. He may read the story of a less ancient but none the less tragic past mirrored in the mangled forms of the storm-tossed and time-worn trees which stand forth as the alpine outposts of the forest primeval. The spirit of reminiscence blows full free upon the visage of those sad and tattered sentinels of that terrible frontier. One need only to possess the power to interpret the reactions of those outposts to catch fleeting glimpses of some of the most severe struggles and "last ditch" stands ever endured by living things. And I would impress my readers with the fact that these gnomes of the heights are living organisms! Many such sentries exposed to the scathing fire of a relentlessly opposing environment have, however, long since yielded up the ghost. Their whitened and eroded forms are being slowly ground away and their dust is gradually being returned to the barren earth which gave it.

The survivors at timber-line tell their several stories only to those who are acquainted with their lives and who delight in reading the dynamic life-histories and the evident struggles with environmental forces endured by poor dumb things, because the trees at timber-line, despite their expressive forms, are no more talkative than their close relatives who enjoy the equanimity of the mesophilous lowland forests.

So I will endeavor to portray in these few pages, and with the valued assistance of a few prized photographs, something of the biologic features characteristic of timber-line in the state of Colorado, and especially something about the peculiarly dwarfed and wrinkled and aged trees with which I have become more or less intimate.

The term timber-line is commonly applied to the upper limit of tree growth, whether that limit is an alpine or an arctic one. Beyond timber-line is the land of "little sticks," where there are no trees, but only miniature bushes, brilliant alpine flowers, mosses and lichens, and here and there enticing expanses of



TIMBER-LINE IS SELDOM A CLEARLY CUT AND STRAIGHT BOUNDARY LINE AT A UNIFORM ALTITUDE. Usually it is very irregular and jagged and it may swing up and down through an altitudinal amplitude of a thousand feet.

beautiful alpine pastures, the real *alps*. We must not understand that the upper border of the forest is in fact a clearly cut and straight boundary line at a uniform altitude or latitude as the case may be. Timber-line is commonly very irregular and jagged, and it may swing up and down through an altitudinal amplitude of a thousand feet or more, even upon a given mountain, or through several miles in the far north. Such fluctuations are related to numerous environmental obstacles some of which will be mentioned in the succeeding paragraphs.

The Trees at Timber-line

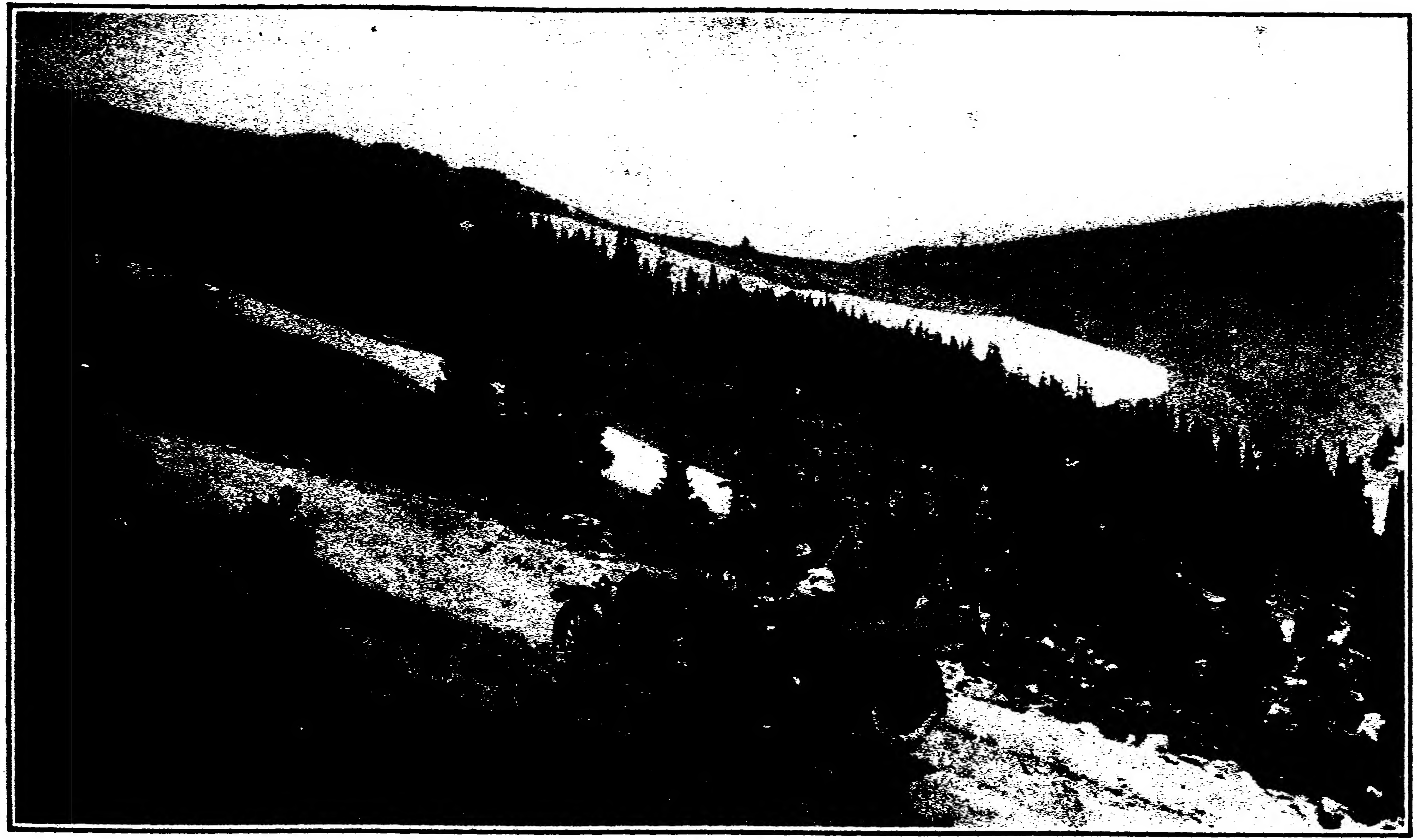
I have already stated that the most fantastic forms and perhaps, therefore, the most interesting phenomena of all in the most alluring medley of biological conditions at timber-line are seen in the dwarfed and wizened gnomes of the elfin-forest frontier. The commonest trees to reach the alpine forest limits in the Rocky Mountains of Colorado are limber pine (*Pinus flexilis*), and Engelmann spruce (*Picea Engelmanni*). Quaking aspen (*Populus tremuloides*), Alpine fir (*Abies lasiocarpa*) and fox-tail pine (*Pinus aristata*) also reach the front line trenches at timber-line, but are less frequently seen in such places.

The Engelmann spruce is seldom seen in the driest and most exposed sites. The species typically reaches its upper altitudinal limit in the form of scattered stands or isolated and more or less dwarfed individuals in the protection afforded by moist canyon heads. In such places one frequently finds a few poorly developed, erect, and excessively branched trees fringed at the base by an impenetrable thicket of scraggly and interwoven twigs produced by the multiplicity of lateral buds and branches. Such springy growths are excellent places upon which to enjoy a siesta, following a difficult climb.

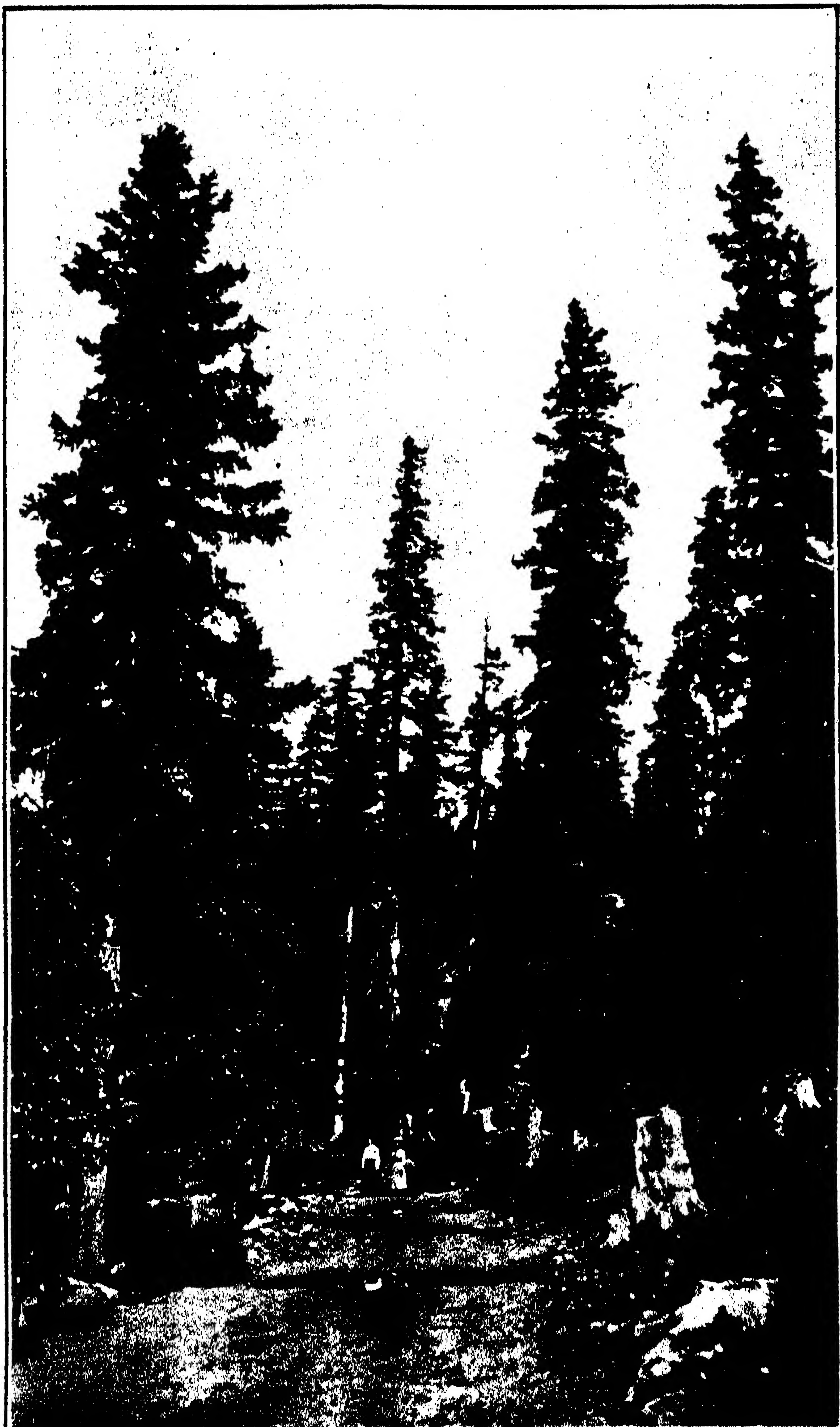
It is quite different, however, for the limber pine which often braves the elements upon the most exposed ridges where the outposts endure the buffeting of the dynamic surroundings for years. This tree is able to maintain a foothold upon dry open tracts in the very teeth of the furious gales that often swoop down upon them from the heights.

Individuality in Trees

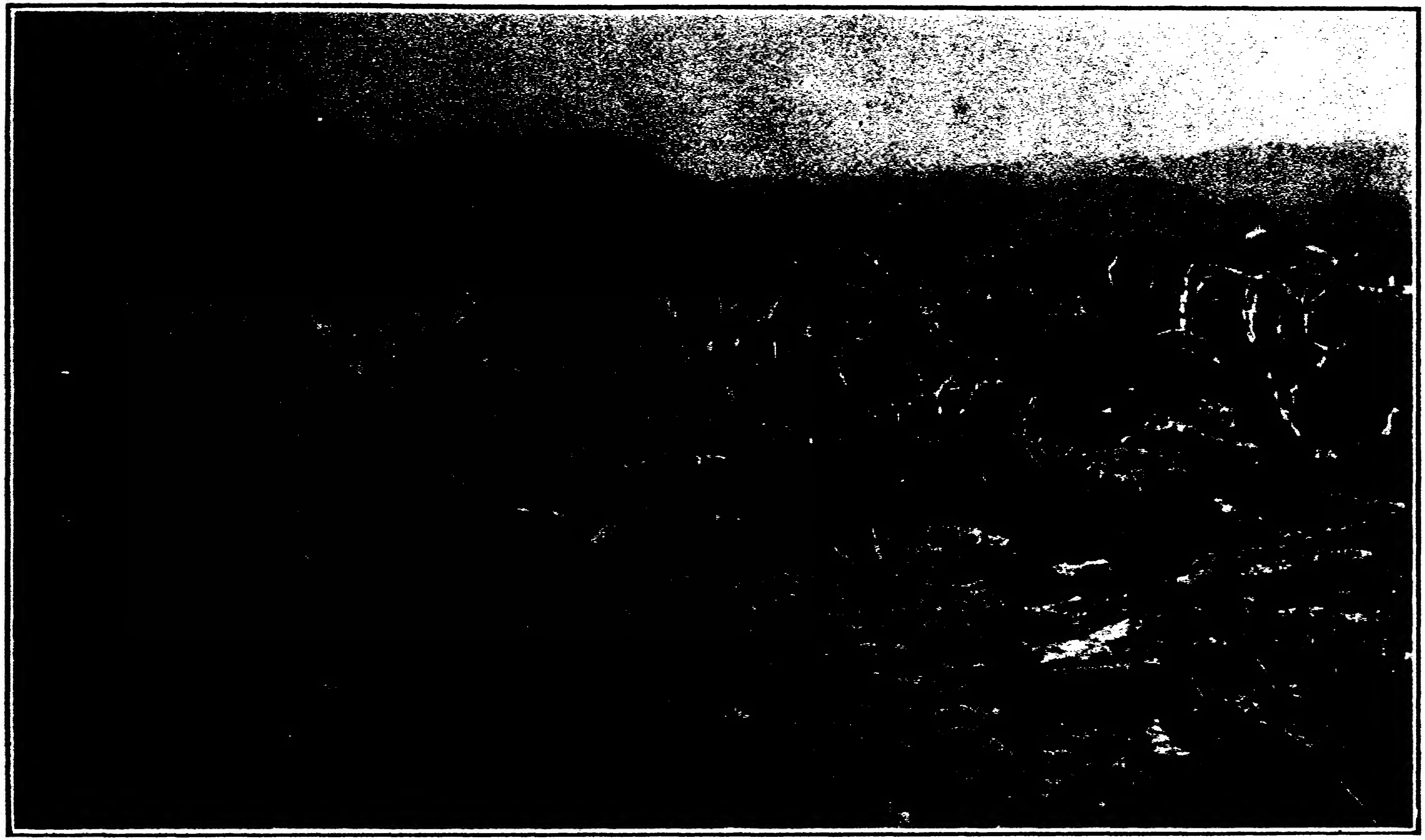
The individuality of the limber pines and the range in morphological reactions to the rigorous factors of their most extreme habitats are exceedingly varied and bizarre and are perhaps not to be equalled by any organism in any environment



APPROACHING TIMBER-LINE WITH THE ENGELMANN SPRUCE. This tree is usually found in the moister habitats of the canyon heads at timer-line. It seldom occurs in the drier and more exposed sites with limber pine.



THE ENGELMANN SPRUCE IN ITS OPTIMUM SITE IS ONE OF THE FINEST OF AMERICAN CONIFEROUS EVERGREENS. It frequently reaches timber-line, but it is seldom found in the most severely exposed sites on that forest frontier.



MOST OF THE TREES WERE BENT TO THE LEEWARD AS THOUGH STANDING IN THE PATH OF SOME MIGHTY BEAST WHOSE TREAD HAD LITERALLY TRAMPED THE FOREST TO THE GROUND WHERE THE TREES WERE MORE OR LESS BURIED IN THE DÉBRIS OF THE AGES.

known to biologists. There are, in fact, scarcely two trees of this species to be found among the pioneers at timber-line that closely resemble each other in their bodily forms. Each tree appears to have worked out the solution of its own individual salvation under great stress and in its own individual manner. All this merely emphasizes the scarcely understood fact that plants do have considerable individuality even if they are not conscious beings.

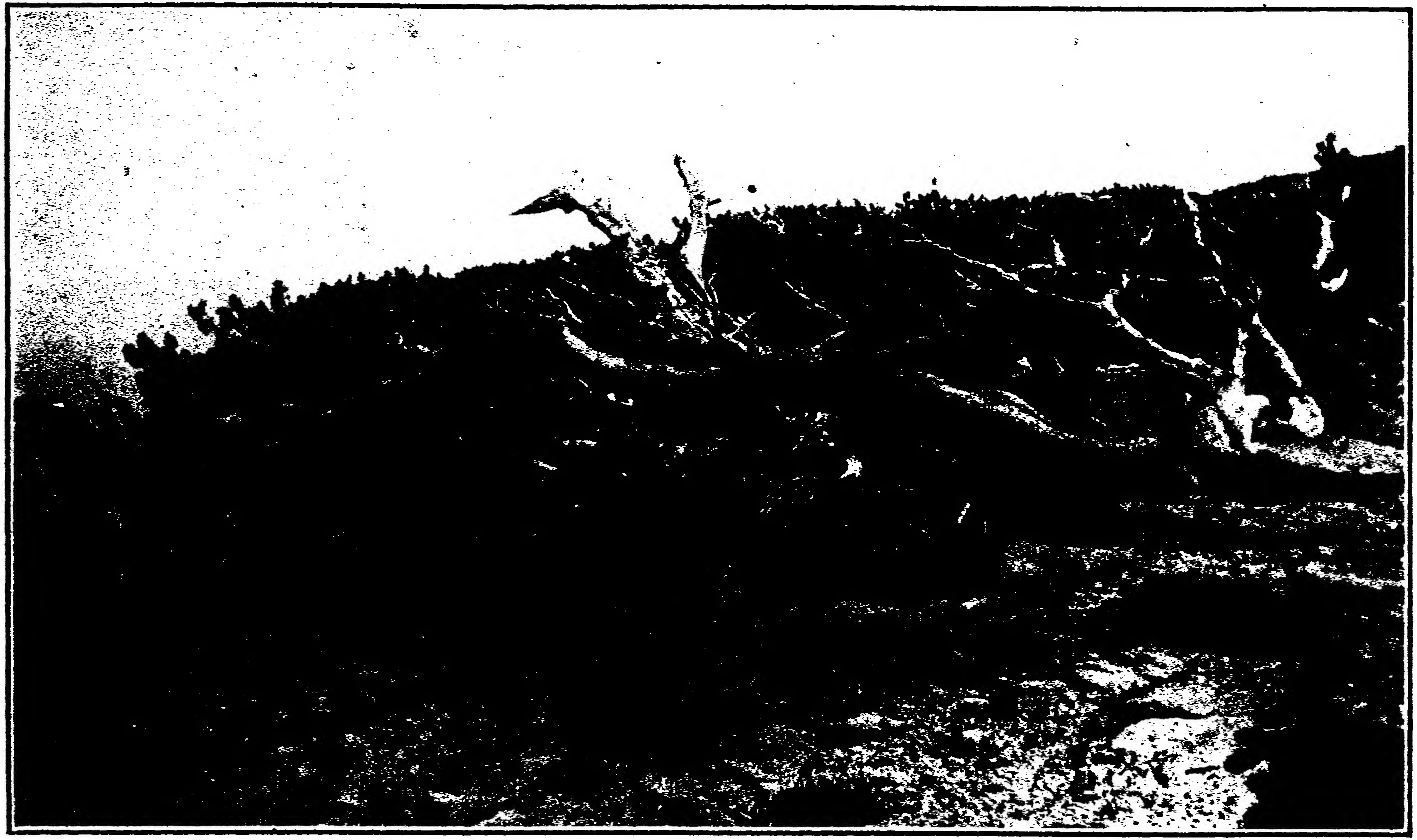
The limber pine belongs to the white pine group, a series of species whose remarkable qualities and beautiful forms are famous among coniferous evergreens. This species is, however, a rather small tree, rarely attaining a height of sixty feet and a trunk diameter of four feet at the base. It is usually a slowly growing, stout, bristly tree from twenty to thirty-five feet in height, with a sturdy, rapidly tapering trunk from one to two feet in diameter at the ground level as it grows in the more congenial habitats of altitudes below timber-line.

Almost every conceivable modification and deformity of the limber pines occur upon the wind-swept alpine slopes and exposed, xerophilous ridges at timber-line. In a jagged area of elfin-wood at an altitude of about 11,000 feet containing several hundred individual trees of this species I was able to study and to photograph scores of morphological variations and eccentricities, the most of them peculiar to the timber-line neighborhood.

Sometimes an odd, squatty form of the normal tree is seen where the blasting effects of the gales are not directly felt. Such trees may be a scant dozen feet tall, but have developed, through the long decades of their precarious life, a rapidly-tapering and gnarled trunk three feet in diameter at the surface of the sterile rock heap in which the cramped roots find anchorage. These fore-shortened trees are often of great age.

Trees of Great Age

One can not judge of the age of these timber-line trees by their size or bulk. If one could evaluate their grizzliness in terms of years he would thereby be enabled to make a closer estimate as to their ages, but that is quite impossible. The layers of growth (the so-called annual rings) in the wood of such trees are commonly so close together or so thin as to be indiscernible to the naked eye. The sheeted layers of wood are often so attenuated that a good hand lens or a dissecting microscope is required to count them with accuracy. I found that some pieces of the wood of the timber-line limber pines which I



The trees lie with their coarse roots firmly anchored in the solid rock of the mountain side, while their heavy trunks stretch away to the leeward like the undulating bodies of ponderous, prehistoric saurians.

brought home from one of my trips were of astonishingly slow growth. Some such pieces were tangential strips of wood, less than one inch in thickness, and by actual count it was found that they contained between sixty and seventy annual layers.

Mr. Enos A. Mills, a well-known writer upon the numerous natural features of the Rocky Mountains, states that there may be great differences in the ages of timber-line trees standing close together and that the size of a tree is no criterion whatever as to its age. He writes of a tree fourteen feet in height and sixteen inches in diameter which was three hundred and thirty-seven years old. Another tree close by was seven feet tall, five inches in diameter, and it had endured the trying life on that frontier for four hundred and ninety-two years! Doubtless many timber-line trees have maintained their uncertain foothold and have pieced out their lingering existence by the production of a thin new layer of sapwood during each brief alpine summer since the time when Columbus piloted his frail caravels across the heaving bosom of the unknown Atlantic.

Wind-Crippled Trees

Besides the diminutive forms of the trees the most evident effects of the timber-line environment are undoubtedly seen in the wake of the winds which blow from a more or less constant quarter. Sweeping over some saddle or booming down the slopes the thundering blasts strike the sentinels of the forest and then sweep onward to the main body of trees farther down the slope. The immediate effect is to produce odd, lop-sided creatures more or less similar to those seen upon windy sea coasts. The crowns of the trees become distorted and bent to the leeward and often the whole tree is thrown out of the perpendicular, with a resultant deformity more striking than the sea-side cripples. The branches on the lee side stretch far out as if in flight before the oncoming blasts. The lateral twigs and the normally erect spray become pounded and woven into most astonishingly abnormal brushes and bristling tufts. The one-sidedness of such trees is frequently still further emphasized because of the failure of the branches to develop on the windward side or by the cutting away of any such branches by the incessant beating of the prevailing wind. I have examined some such trees in which there were absolutely no external indications of there ever having been any lateral branches on the windward side of the trunk.

The extreme effect of the wind combined with heavy snowfall is seen in the development of prostrate trees lying upon

SUCH AGED AND SQUATTY TREES MAY BE A SCANT DOZEN FEET TALL, BUT THEY HAVE DEVELOPED, THROUGH THE LONG DECADES OF THEIR PRECARIOUS EXISTENCE, A RAPIDLY TAPERING AND GNARLED TRUNK THREE FEET IN DIAMETER AT THE BASE. They may be more than five hundred years old.

THE INCESSANT CHISELING OF THE WIND FINALLY ENDS THE LIFE OF THE DEFORMED STRUGGLER AND THEN ITS LIFELESS BODY STANDS OUTLINED AGAINST THE HORIZON LIKE THE EMACIATED FORM OF A CRIPPLED GIRAFFE GROWN GAUNT FROM LACK OF FORAGE AND DRINK.

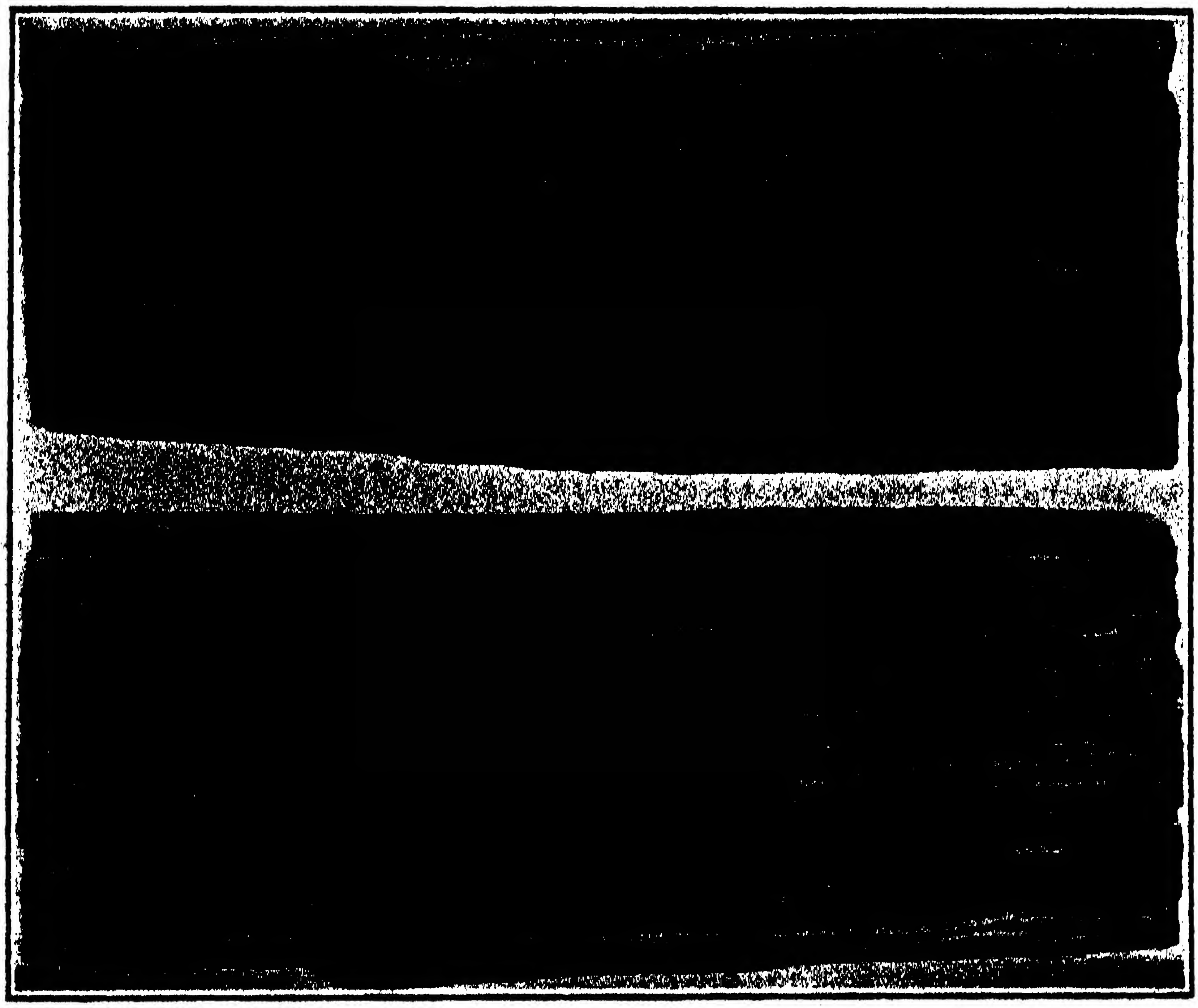
AFTER THE BARK HAS BEEN PULVERIZED AND WEATHERED AWAY THE TEETH OF THE WIND CONTINUE TO ETCH THEIR WAY INTO THE VERY WOOD ITSELF.

the stony surface of the wind-blown mountain floor. These trees lie with their coarse roots anchored firmly in the solid rock of the mountain side, while the heavy trunks stretch away to the leeward like the undulatory bodies of ponderous prehistoric saurians. One such tree eighteen inches in diameter and twenty-five feet long had had all of the branches on the upper surface planed away by the abrasive sand and sleet carried by the wind, while the living twigs were segregated in the usual tangles toward the end of the prone form. The flattened forest at that point as portrayed by the above trees illustrates the unmistakable influence of the heavy snowfall at high altitudes. None of the trees in that prostrate group raised a twig higher than five feet above the ground. The most of them were flattened out and bent to the leeward as though standing in the path of some mighty beast moving with the breeze and whose tread had literally tramped the forest to the ground, where the trees were more or less buried in the débris of the ages. In less exposed situations the trees assume a more nearly erect posture, but even there the knotted, twisted and burly forms are sometimes riven by lightning and disheveled by the blasts of Boreas and his heavy mantle of snow until they totter like a drunken man and almost fall to the earth.

The dwarfed, gnarled, twisted and sprawling trees at timber-line have been known to botanists by the term *Krummholz*, which is German for *gnarled wood*. The term was originally applied to the high altitude form of the mountain pine (*Pinus montana*) of the Alps. In late years it has been used widely as a general term for the scrubby and bizarre growth of woody plants at or in the vicinity of timber-line on mountains in any part of the world. It is surely a very expressive and useful term.

As one strolls among the various forms at timber-line he occasionally finds a curious entanglement of scraggly, woody growth lying in the shelter of a low boulder or snuggling beneath the projecting angle of a cliff. In such places the branches and leafy tufts are trimmed smoothly away on a level with the surface of the protecting obstacle. The twigs of such trees often become so densely interwoven and so tough that one may walk over the prostrate, hedge-like form without breaking far into the brush beneath the surface.

The degree of exposure to the wind and the influence of heavy snow appear to be most effective in modifying the forms of the trees at timber-line. The effects of snow are also seen far below the upper limit of tree growth, particularly in



SO DEFTLY ARE THESE WIND-CARVINGS EXECUTED BY THE FINGERS OF THE WIND THAT THEY DEFY THE BEST EFFORTS OF A SKILLED WOOD CARVER WHO WOULD ATTEMPT TO IMITATE THEM. The above pieces show the effect of wind erosion in comparatively straight grained wood.

thickets of quaking aspen trees. There one occasionally notices that the trees are bent and twisted and crooked into multifarious contortions at a certain height. I once saw such a striking condition in a grove of young aspens about twenty feet tall. The distorted portions of the trunks were completely confined to a zone between five and seven feet above the ground. And every tree of the several hundred in the grove was affected. Very evidently the cause of such a peculiar-looking condition was to be found in snow relations, coupled with the growth habits of the trees.

Wind, the Wood Carver at Timber-line

An additional point of great interest in connection with my studies of the *Krummholz* at timber-line in Tahosa are the fantastic wind-carvings produced in the wood of the decorticated tree trunks. The winds at timber-line often blow with a high velocity and then they carry with them quantities of sharply angular rock fragments weathered away from the very back-

bone of the mountains. During the long winter months this load of abrasive material is augmented by the presence of quantities of snow and ice spicules. The fine mineral particles have been so recently removed from the parent rocks that they are exceedingly sharp-angled and pointed. This feature increases their abrasive influence as they are carried along by the wind. A winter gale thus laden, sweeping over the heights, may in truth be said to possess teeth, the "teeth of the storm."

I have already pointed out the fact that the windward sides of the tree trunks at timber-line are sometimes devoid of branches. Frequently the bark also has been cut away from that side. The tree may be nearly girdled by the powerful grinding effect of the sand and sleet carried in the high wind. Often only a slender longitudinal belt of living bark is left on the lee side of the tree to carry the necessary life-giving substances from the meagerly developed expanse of foliage to the hard-working root system pinched and cramped in the crevices of the rocky substratum. The breakage of this connection is doubtless an important factor in the final death of the trees which grow in the most exposed sites. The incessant hammering and chiseling of the wind ultimately ends the lingering life of the deformed struggler and then its lifeless body stands there outlined against the horizon like the emaciated form of a crippled giraffe grown gaunt from lack of forage and drink.

After the bark has been pulverized and weathered away the teeth of the wind continue to etch their way into the wood itself. The thin, young and less resistant sapwood is soon removed and then the harder, resinous heartwood is attacked, upon the surface of which are cut the intricate traceries of the fingers of the wind. So deftly are these carvings executed that they defy the best efforts of the most skillful wood carver who would attempt to reproduce them. Their imitation is impossible because the fingers of the wind have felt out the variations in hardness and structure of the wood with a delicacy of perception far beyond that possessed by a mere human being. The result is the production of wood carvings of remarkable beauty and variety. The unevenly resistant wood and the intricate variations in the grain of the slowly and irregularly growing wood are strikingly mirrored in the variation of detail in the individual trees. The most beautiful effects of all such wind influences are seen in those tree trunks and branches in which the grain is more or less distorted. Thus the spiral growth, wavy grain effects, and the extreme disturbances of normal wood structure in knots and burls, coupled with variations in wood

density, are emphasized in a very remarkable and often beautiful degree upon the dead surfaces of the storm-tossed trees at timber-line. The erosion of the woody bodies continues after death and serves still further to multiply the fantastic and weird effects of the environment in which the *Krummholz* is developed. Even the fragments of the dismembered bodies of the ancient gnomes are blown about and sculptured until they lose nearly all semblance to any plant structure. Waugh's uniquely illustrated and more or less spooky fairy tale, "The Clan of Munes," might find a natural sequel among these grotesque forms at timber-line.

Timber-line Contrasts

It is only with great difficulty and careful study that the occasional visitor is able to acquire an adequate appreciation of the peculiarly rigorous environmental conditions at timber-line. This is particularly true for him whose visits to timber-line are made only during the relative peace and quiet of a warm summer day when the alpine meadows and fell-fields are ablaze with the blooms of gorgeous wild flowers and when all living nature on the heights is humming with the busy opportunity for life and propagation afforded by the short hours of a brief growing season. The first blush of vernal bloom has scarcely faded upon the alpine heights ere the seeded capsules of arctic willow and primrose and the hoary plumes of Dryas give warning of the early approach of old Boreas with his host of forces to try the last fiber of every living thing at timber-line throughout the long, cold winter. No more striking contrast can be found in nature than that seen in the silent places where brilliant wild flowers bloom in lavish profusion within the shadow of frowning cliff and the storm-marked and ghostly *Krummholz*, where the youthful brook gurgles along its silvery path hard by where the trustful Ptarmigan silently guards her young, and where the warm sunshine and cloud-bedecked, summer sky covers all. John Muir's words are expressive in this connection: "Nature's sources never fail. Like a generous host, she offers her brimming cups in endless variety, served in a grand hall, the sky its ceiling, the mountains its walls, decorated with glorious paintings and enlivened with bands of music ever playing."

Besides the limber pine and the Engelmann spruce which enter most prominently into this sketch there are several other species of coniferous trees which reach timber-line in other por-

tions of the continent. White spruce (*Picea canadensis*) and balsam fir (*Abies balsamea*) in the New England mountains; alpine fir (*Abies lasiocarpa*), white-bark pine (*Pinus albicaulis*), and fox-tail pine (*Pinus aristata*) in the Rocky Mountains; and the mountain hemlock (*Tsuga mertensiana*) from Oregon to Alaska are other trees which share in the development of timber-line phenomena.

The altitude of the alpine timber-line varies more or less inversely with latitude, *i.e.*, the upper limit of tree growth on mountains is encountered at a lower altitude as one travels northward, as latitude increases the altitude of timber-line decreases. In the far north timber-line comes down to the shores of the icy sea shortly beyond the Arctic circle. The altitude of timber-line in the Canadian Rockies varies from 5,000 to 6,000 feet. On Mt. Rainier it is about 7,000 feet, while in central Colorado it is reached between 10,000 and 12,000 feet. The highest timber-line in the world is said to occur in Mexico, as on Mt. Orizaba, at an altitude of 14,000 feet, which is reached by *Pinus strobiformis*, one of the southwestern white pines.

The Causes of Timber-line Reactions

The limitation of tree growth at certain altitudes in the mountains has never been adequately explained. Unquestionably the cause or causes are to be found somewhere in the maze of interacting or overlapping factors brought to bear upon the life at timber-line. The ecological relations there are apparently very complex and until much more quantitative research has been completed within those dynamic habitats biologists will be unable to point out the cause of timber-line with surety. The effects of wind are unmistakably chiseled into the prominent reactions of the trees, some of which have been poorly and inadequately described in the preceding paragraphs. The effect of heavy and long-persisting beds of snow are probably of importance in restricting the growth of forests at high altitudes. Certain investigators have felt that snow is the chief factor which inhibits the development of a forest of normal trees at certain altitudes and is responsible for the development of alpine grasslands instead of forest. Others believe that the desiccating influence of the winds, coupled with a deficiency of available water supply at the roots and a low temperature, largely explain the stunted nature of the woody growth at timber-line. Atmospheric rarity, intense insolation, rapid radiation, low relative humidity, and short growing seasons have

also been proposed as playing important rôles in the production of alpine dwarfs and possibly in actually causing timber-line.

Experiments appear to have demonstrated that the dwarfing is actually due to the alpine conditions. Portions of alpine plants moved to the lowlands promptly awakened from their dwarfed state and developed the characteristic lowland forms with tall stems, while portions of lowland plants established in alpine sites promptly became dwarfs.

Snow-cripples, drought-cripples and dwarfs as well as wind-cripples and dwarfs probably occur within timber-line areas. Numerous similarities existing between alpine and polar growth forms and the vegetation of desert lands have led to the belief that the whole relation is one of aridity. Arctic-alpine habitats have been included among the desert series in ecological classifications of habitats.

The prevailingly low temperature summation is doubtless of great importance in limiting the activities of the plants at timber-line and consequently in modifying the growth forms most efficient or possible there. In this connection I once recorded some observations upon the matted forms of the alpine pink (*Silene acaulis*) growing in a gravelly slope on Mt. Garfield in the vicinity of Pikes Peak. The flat, bristly, mat-like plant, beautifully radiate in form, was about eighteen inches in diameter and was growing where it was partially shaded by a large boulder. The shaded portion of the mat was evidently not in as good condition as the portion which received the direct rays of the sun, in fact it possessed many of the well-known weakly characteristics of shade plants in general. But the influence of the sun (heat or light) was very evident the day I made the observations because of the production of flowers on the plant. The arctic pink at blooming time is often literally covered with scores of the beautiful pink flowers about five-sixteenths of an inch wide. The lighted portion of the mat in this case, the portion receiving the direct rays of the sun at noon-day, was about one half of the whole plant and was blooming profusely, while the portion in the cool shade of the rock showed very few open flowers or flower buds.

A primary task of all green plants in timber-line situations is certainly to utilize the heat and light of the sun in the manufacture of the food supply necessary for leaf and root formation and for reproduction if they are to remain in such places. Essential nutritive materials must be secured *via* the root-system from the cold soil solution at the same time. Any condition of

air or soil which tends to block these fundamental processes for long periods of each year strikes at the very life of the plants in question, and consequently would exert a significant influence upon the initial establishment and the subsequent success of the plants on the heights.

These are but a few of the impressions and problems which are suggested on every side to the inquisitive wanderer among the plant pigmies at timber-line in the land of Tahosa.

THE SOCIAL NEED FOR SCIENTIFIC PSYCHOLOGY[1]

By Professor KNIGHT DUNLAP
THE JOHNS HOPKINS UNIVERSITY

IT is a matter of common report that never before has there been in the United States such an interest in psychology as is now evidenced in manifold ways. There is an increased enrollment in psychology classes in colleges and universities. There is an increased sale of books bearing upon various phases of psychology, and a heightened activity in the writing of such books. There are demands coming from the commercial and industrial fields, for experts in psychology, and for psychological methods. There is an awakening of interest in psychology in the ranks of those who have to deal with social and economic problems, and there are signs that among the members of the medical profession the need for psychology will soon be recognized.

There is an especially significant demand for applied psychology; not only for the applications of mental tests, but also for the application of the laboratory research methods to problems of industry, of education, and of hygiene. The resources of my own laboratory, for example, have for the past year been very largely devoted to work laid upon us by the American Committee for the Study of the Tobacco Problem. It is noteworthy also, that large industrial and commercial corporations are now seeking for experimental psychologists to conduct research for them along specific lines of scientific need.

The increase of interest in psychology is being shown also in the great vogue of the mental testing of school children, and in the application of mental tests to applicants for entrance to college, as well as in the concomitant rapid increase in the types and forms of single and composite tests.

The interest which is apparently active, is unfortunately not shown in the way on which psychologists themselves would lay the most stress, as indicating a substantial, rather than ephemeral interest: namely, in the increased provisions for the adequate training of psychologists, and the increased provisions

[1] Presidential address before the Southern Society for Philosophy and Psychology, New Orleans, April 23, 1920.

for the effective working of psychologists along the lines of pure science. Perhaps this provision will come as a natural result of the wave of popular interest: perhaps it will not come unless definite measures are taken to bring it about. This uncertainty must cause us to pause in our self-congratulations, to consider whether, after all, psychology is experiencing a healthy growth, or a process of inflation, or even a sort of parasitic growth which may sap its strength and lead ultimately to its downfall and disrepute.

We must admit that the large growth of interest of which I have just spoken, is a growth in interests in various sorts of things, which happen to be included or held together by the name "Psychology," but whose actual affiliations with each other require careful determination before we can accept the mass as one subject. Some of the lines of growth of so-called psychological interests are destructive of other lines; and while it is true superficially that there is this great increase in what is called "psychology," it may not be true that this interest coincides with that which many of us hold to be the essential spirit of psychology.

It is a matter of common knowledge to all, that not every one who labels himself a "psychologist," or to whom the label is tossed by journalist and popular writer, is entitled to the designation. We are frequently reading, or being told, that "psychologists now admit thus and so": or, "an eminent psychologist claims such and such": and then, on further inquiry, finding that the eminent psychologists referred to are Professor Oscar Loon, Caroline Greenfield, and W. H. Spinks, M.D. We find also an appalling number of self-annointed "psychologists" in the industrial field, industriously selling psychological gold bricks to the gullible business man, and raising thereby obstacles to real industrial psychology which will long endure.

It is sometimes difficult to explain to the layman the difference between the real psychologist and the alleged psychologist. We can, however, usefully point out a fairly accurate basis of discrimination based on the endorsement of the American Psychological Association, and deny that any one not a member of that Association can be recognized as an "eminent" American psychologist unless specifically endorsed in some other way by that association. The conditions attending the present wide interest in psychology and pseudo-psychology make it imperative that we guard membership in the American Association more carefully in the future than we have in the past, and admit to official recognition no one who may use his endorsement to the detriment of science.

The assumption by unauthorized parties of the function of the psychologist is not, however, the only symptom of the seriousness of the situation in which psychology finds itself at the present time, nor is it the most serious symptom. We might expect to find a common interest in psychology and a common purpose in respect to it, among those who not only are endorsed by the official company of psychologists, but are still further accredited by specific appointment to positions in psychology in our great institutions of learning. But here we find so great a diversity that it would seem that an increase in interest in what some of these men call by the name of psychology is a withdrawal of interest from what some of the others call by that venerable name. We find in the list of accredited psychologists, for example, those reactionaries who would have no advance beyond the conceptions of John Locke and Wilhelm Wundt, and also those radicals who would altogether abandon psychology as it is historically known, and would admit the possibility of no biological science beyond physiology.

Our diagnosis of the weakness of the present psychological situation can not stop even here. We find among us those who, regardless of their being otherwise reactionaries or radicals, or even moderate conservatives, are weakening in their devotion to science; and to whom her hard discipline is becoming so irksome that they are favorably disposed to that mysticism which is ever the enemy outside our gates. These faint-hearted ones have sounded the praises of the alien goddess, and have proposed the surrender of the citadel to her forces. This danger may not be so serious as it seemed two or three years ago, but it is not yet absent.

Such is the situation. And in the face of this, the need in society for a real and constructive psychology is becoming daily more specific and more urgent. This need we seem to be supplying only in a small measure, and I believe we can supply it with any degree of adequacy only by means of a greater emphasis on the scientific aspect of psychology.

To make my meaning clear, I must insist upon the distinction between the various arts which derive their support and extension from psychology, and psychology itself. I shall insist in the second place upon the distinction between psychology in the general or inclusive sense, and that particular sort of psychology to which I am here applying the term *Scientific*. In order to further my exposition I shall also assume two postulates which I do not care to defend at the moment, but which I think no one would wish to dispute.

The first postulate is: That a science which makes no appreciable progress in its conceptions and methods is dead. The other is: That a proposition to sweep aside the history of a science and start completely anew is suicidal; that it is an admission that the newly proposed scientific foundation is as insecure in value as the rejected foundation is declared to be.

Of the value of the psychological arts there can be no doubt. I do not wish to be understood as in the least hostile to the arts, for such would be a complete misunderstanding of my meaning. On the contrary, I am profoundly interested in the expansion of these arts, and am personally engaged in the furthering of several of them. Nevertheless, my interest in the present discussion is in the science which underlies these arts, and which has values not only in its fostering these arts, and as pure science, but also in direct relations to society which are entirely independent of its functions as exercised indirectly through the psychological arts.

It has been said by some of those who were concerned in the application of the well known Army Mental Tests, that there was no psychology involved in either the construction or the application of these. Some of those here present have heard this statement emphatically made. Men who themselves are presumably well grounded in psychology, and who have held academic positions in psychology, have averred that in the army work they neither used nor needed anything that they had learned in any course in psychology or in a psychological laboratory.

I must say that, with all due respects to those who make this claim, I do not think they are right in their analysis. If this were so, it would indeed be a strange thing that the work of psychologists was required for the construction of the tests, and for the organization of their application: and we should have to look for some reasonable explanation for the fact that this work waited on the efforts of the psychologists. But nevertheless, underlying this claim there is a fact which we must give consideration. We must admit that after such tests are compiled and organized, the giving of such objective tests is merely a matter of technique, requiring a special clerical training, which may be acquired by any one of the requisite native intelligence and general education, without any orientation in the matters which are generally contained in lecture and laboratory courses in psychology. It is also true that a considerable amount of success has been obtained in the selecting, if not in the construction, of such tests, by persons wholly devoid

of psychological training: in fact, in the field of commercial applications by men whose psychological training has a negative value.

It is true, moreover, that the greatest source of the evil which flows from the widespread "mental testing" carried on in schools by enthusiastic teachers, and others, is not the ignorance of general psychology which these "wild" testers show, but their lack of training in the technique of giving and interpreting the tests. The successful giver of tests need know nothing of the results of research on memory, or space perception, or any other department of psychology. It makes no difference for his work whether he assumes that the soul is a real spiritual essence, or a material substance which is visible after death as a ghost, or that there is no soul. He may believe consciousness to be an act, a stuff, or a myth. He may be a Christian Scientist, a Theosophist, or a Hegelian. He may know nothing of the niceties or the difficulties of threshold determination.

It is true that the fundamental parts of the technique required are inculcated in psychological laboratories. But so is, in far greater measure, the technique which the oculist requires (and usually does not possess). This would be a relevant matter only if we should find out that, after all, psychology is nothing but technique—a conclusion which I certainly shall not admit as yet.

What we are bringing out clearly here is, that the whole subject of mental testing is an *art*, and that like any art, it may go a great way without any scientific foundation. But this is not the same as the admission that there *is* no scientific foundation, or that the art can without detriment to itself, dispense with the foundation. It is true that we have at least one example of an art which has reached a high stage of development with practically no scientific foundation at all. This is the art of music, which is a most finished and practical art, although there is almost nothing in the way of a scientific basis for it. But we need not stop to point out that the conditions under which this art has arisen are sharply different from those surrounding other psychological arts.

Other psychological arts which might be mentioned along with what for convenience we call "mental testing" are: hypnosis, character analysis, and education in the restricted meaning of the term. The first two of these have languished for lack of a psychological scientific foundation which I believe will eventually be supplied, and the third is the grand example of the value of that foundation.

It is not necessary for my purpose to go further into details on this point, but rather is it expedient to consider the nature of the science which I have assumed as underlying the arts.

The two great and inexorable conditions laid upon every science are that it shall in the first place be *empirical,* and in the second place that it shall be *logical.* Without an empirical basis of fact, even with the utmost logical consistency, we can evolve nothing more than an ingenious speculative system. Without logical consistency in reasoning, the attempt to explain facts results in nothing more than mythology. These conditions are laid upon psychology no less than upon physics and chemistry, and the chief hindrances of psychology in the past have been the results of the difficulty in approximating to both of these ideals. At the present time, the movements which threaten to disrupt or destroy psychology can be analyzed into omissions of scrupulous regard for one or the other of these great principles.

Many attempts have been made to construct psychological systems on a defective empirical basis. Such a system was constructed with brilliant regard for consistency by William James, and called by him the "stream of consciousness." It was finally discarded by him because he subsequently recognized that he had omitted the empirical basis, and so had elaborated a theory of the "mind" defective only in one respect, but in the vital respect, that there was no evidence that any such mind ever existed.

In a still more thoroughgoing way, Malebranche constructed the system so beautifully presented in his *Dialogs:* the system which so impressed John Locke and George Berkeley that they expanded it, and passed it on through Hume and Kant into the Anglo-German psychology which still clings to it, in spite of the unmistakable lack of an empirical basis.

The most recent construction of this *a priori* sort is the psychology which calls itself Behaviorism, which reaches a conclusion apparently quite different from that of the reactionary psychology, but by the same method. And of the making of more systems there is no end, so long as we start from concepts instead of facts.

The effects of the neglect of the other principles of science (logical consistency) are perhaps most strikingly illustrated in the system or group of systems which are variously known as "Psycho-analysis," "Freudianism," or "The newer Psychology." While the fundamental defect of this system is its lack

of an empirical basis, it reaches its most astonishing results by the complacent ignoring of the elementary principles of deductive and inductive reasoning. But psycho-analysis is by no means the only sinner in this respect, even if it be the most flagrant one. So long as we maintain our calm indifference to the meanings of the terms we use, preferring to keep the meanings vague so that we can juggle them as we need to make them serve our purposes, psychology is certain to be prevented from reaching its place as one of the sciences.

There is a consensus of opinion historically as to the data with which psychology ought to start. Aristotle, whom we rightly regard as the founder of the science, mapped its empirical basis with fair accuracy. The psychologists who followed him, even Malebranche and his disciples, were really seeking to start from the same facts. We are by no means justified in discarding the efforts of these men, but rather we owe it to them, as to their heirs, to better their efforts and avoid their failures, as we trust that our successors will better our efforts and avoid our failures.

The situation in which psychologizing begins, and hence, from which the science of psychology starts, is *the being aware of objects:* and unless psychology starts from this it does not start at all. This is the history of the science, and this is the conclusion to which any one must come who searches to-day for an empirical basis on which to build a science which will not be merely a misnamed part of some other science. On the other hand, this is a real empirical basis, since *being aware of things* is an undeniable fact, however we may ultimately explain or analyze it.

This empirical basis at once excludes behaviorism, which may be a perfectly legitimate part of physiology, but as an attempt at psychology it is ruled out as non-empirical, since it does not stand on the basis of the complete empirical situation.

Further examination of the *facts of experience* (as we customarily name the empirical basis of psychology) reveals three facts, which are revealed *as facts*, and not as inferences. First, that awareness occurs in typical cases and in very many cases, in conjunction with bodily activities of the type which we designate as *reactions*: that, for example, the awareness of a colored object is strikingly bound up with such reactions as touching the object, moving the head, or with reactions of the visual organs. Second, that there are two distinguishable ways of being conscious of a thing, one of which we commonly designate as *perception*, and the other way as *imagining* or *thinking*.

Third, that perceiving and thinking alike have in very many cases a peculiarity which we roughly describe as personal; *i.e.*, that each occurrence of awareness tends to have something about it, a "reference," which we express by saying not merely "perceive," but "I perceive."

Now these are empirical facts. And by continued observation we make other and more detailed observations of fact. But it is important to note the limitations of that which we observe, and the ease with which we pass from these to assumptions which we subsequently confuse with observed facts. Descartes, for example, after pointing out the personal nature of consciousness, assumed it to be a universal peculiarity, and assumed that the "I" has certain characteristics such as *substantiality*, which are not empirically observable. Others have assumed that the *awareness* (which is the abstract term for the several acts, or facts of being aware) is itself a thing, and capable of being an object of awareness. Others have assumed that the *awareness* and the thing *of which* I am aware are identical. These assumptions, upon being made, lead to systems of psychology which might possibly be true, but which are not empirical. The assumption of the identity of the *awareness* and the *thing of which*, has had especially serious results, since it permits the substitution of the one for the other in reasoning, leading to complicated conclusions which have only conjectural validity, and hence make the whole system conjectural.

Scientific psychology, because of its compulsion to be scientific, must avoid these *assumptions* of fact. And yet it can not advance with the mere observation of detached and fragmentary details. It, therefore, having established itself on a scientific empirical *basis*, adopts the scientific *method* to which it is now entitled, namely, the framing of *working hypotheses:* and the progress of psychology, like that of all other sciences, is solely a matter of the framing, modifying, and rejecting of working hypotheses, on the basis of empirical observation and through close logical reasoning.

The primary working hypothesis of modern scientific psychology, arrived at by a long series of modifications, is the *reaction hypothesis*. This hypothesis is to the effect that awareness is always conjoined with reaction, or with vestigial reaction. This second clause is not to be neglected, as the hypothesis is not valid without it. There are various ways of expressing the hypothesis, which are practically equivalent, but which have differing appeal for different psychologists. Thus, I prefer to say that awareness is *caused* by reaction: but those

who have a definition of cause which differs from the one I would accept may object to that statement.

This principle, however we may formulate it, is a *working hypothesis*, and nothing more. But with prolonged observation failing to show positive exceptions, and with verification by the usual scientific procedure of *deduction and test*, it becomes a fixed principle, valid, like the law of gravity, so long as we acknowledge its nature; and it is subject, like that law, to modification when facts are found which indicate the necessity of modification.

The scientific results of this hypothesis are far-reaching; explaining phenomena already observed; initiating research along various lines in which the consequences of the principle can be deduced and put to test; and correcting inadequate conclusions of the past based on less adequate hypotheses. Into the details of these we can not here go, but I may point out as an extreme example, that "innate ideas" which were so impressively demolished by Locke, are now by no means to be ignored, but that on the contrary, their existence is quite probable, as biological analogies suggest they should be. Other important consequences I shall mention later.

The empirical basis of scientific psychology excludes the Malebranchian dualism of mental object and physical object, and with it the tedious sham battle between "interactionism" and "psychophysical parallelism." It also removes the bugbear of solipsism, which has darkened the lives of not a few psychologists of the past. These results are not due to the working hypothesis, although strongly consistent with it, but are the direct result of insistence on *empiricism*. In these respects a concrete progress is attained at once, and hence we may reasonably designate attempts to revive the psychology of "mental objects," or "observable mental states" as reactionism, and like all reactionism, a strong ally of radicalism, which in this case is represented by behaviorism.

Scientific psychology, as I have been describing it, is the legitimate and desirable outgrowth of the scientific progress of the past, and neither on the one hand a revolutionary program, nor on the other, an undue reliance on the accomplishments of our fathers, which no longer suffice in the changing order of social needs. And it is the social need of the fostering of this scientific psychology of which I wish especially to speak to-night.

One of the social problems now confronting us, and one with which scientific psychology is especially competent to deal, is the enormous spread and influence of mysticism and pseudo-

mysticism. Perhaps the pseudo-mysticism of spiritualism, telepathy, and all the train of table-tipping, ouija-boarding, levitation and dowsing which goes with these, furnish the most spectacular anti-scientific demonstration of our times. Yet the growth and power of philosophical mysticism, with its definite principles, and fully oriented antagonism to scientific method, is possibly a more serious danger. If one takes account of the remarkable increase in the sale of the books of Underhill, Inge, and others who represent to-day the ancient theories of Plotinus and of Dionysius the Areopagite; if one considers the increased number of such books, and the active propaganda of the mystics in the magazines of supposed culture; one will be impressed with the fact that this system is at least as fully alive and influential as it was in the days of Meister Eckhardt and Tauler.

Philosophical mysticism makes its attack upon science through the rejection of the psychological doctrine of knowledge; and if it can succeed in overturning this, its demolition of the fundamental methods of all science is well begun. Psychology is, in short, the keeper of the gate against this enemy, and is responsible to the whole of science for its defense.

The psychology of the past has fought a good fight against mysticism: it is demanded of us that we fight a better fight. This we can do only by consolidating our ground and improving on the weapons which have so far served; we can not do it by throwing away our arms and abandoning our advantage. Scientific psychology is a consolidation of our ground, because it makes the scientific doctrine of cognition, hitherto somewhat vague, precise and definite, and knits it up with our great fund of acquisitions in biology. No one can accept the fundamental hypotheses of scientific psychology and be in the least mystical. We have progressed beyond the loose conception of a consciousness which may have two, or three, or four, or more different varieties within it, and which is confused by the baffling questions of parallelism and interactionism. We have developed the conception of a single sort of consciousness whose conditions are definitely known, and this conception is so linked with empirical facts and the fundamental working hypothesis as to preclude the possibility of a "third kind of knowledge." Moreover, the very facts of the mystic experience itself are so completely explained on the reaction hypothesis, that the mystics are made to testify to the futility of their theory.

Against the pseudo-mysticism of spiritualism and its occult train, psychology is again the defender of the scientific faith. So well has psychology maintained its honor in this respect,

that it is obvious to him who runs, that the study of psychology is the best possible antidote against occultism. The very fact that the company of scientific men who have fallen into the snare of the "strange woman" of occultism is conspicuously devoid of psychologists is significant. And the scientific psychology based on the biological reaction is more solid, and better prepared against this enemy than was the older psychology. Since it bases all conscious processes on stimulation, and makes thought, as well as perception, depend on reaction, it can more easily explain the lack of evidence for telepathy on the one hand, and on the other hand it can explain how the sincere medium can be deceived by the occurrence of expressions of which she is not conscious until she speaks or writes them. Through its keener understanding of the relation of motor and conscious processes, moreover, it facilitates the work of detecting the mechanisms through which the apparently occult effects are produced. Its fighting superiority in these regards, over the psychology which preceded it, is evidenced by the fact that it is never driven to refuge in the depths of the subconscious or unconscious, as the older psychology sometimes was.

In the fight against mysticism and pseudo-mysticism, psychology has a duty to perform, both to science and to society, which it can not shirk. And it can not perform this duty through devotion to the psychological arts. The highest development of mental testing, for example, though immensely valuable in other ways, can have no function in this battle. Behaviorism, on the other hand, is an avowed pacifist doctrine which abandons the battle from the start, by disclaiming any responsibility for that over which the battle is waged. If our enthusiastic devotion to the psychological arts diverts so much attention, and so much energy, from the scientific work in our laboratories and the scientific instruction in our systematic courses that we go back upon the work of our fathers, and forsake the sacred task of defending our sister sciences and our culture: if we neglect the duty that they have entrusted to us: then our gains are to be counted losses, and our pride in our accomplishment is a disgrace.

The demand for scientific psychology to withstand mysticism and occultism is after all a demand laid upon it as the representative of the historic stem of psychology, and it might be a question whether, in spite of the claims I have here made, it can fight this fight better than its mother, or whether it fights with any other weapon than those she has used with honor. We may indeed pass this point over, pointing out only that the

fight is laid at least upon the lusty child as well as its mother, and that psychological radicalism yields the fight altogether.

There is, however, another force arrayed against biological science and against social progress which nothing but scientific psychology seems able to withstand. This force is the so-called "new psychology" or *psychoanalysis* of Freud and his followers, which lays claim not only to the field of psychology, but also to the fields of literature, art, religion, history, politics, and archeology.

Psychoanalysis threatens the older psychology not so much with demolition as with absorption. Developing its doctrines on the very conception of a world of psychic objects or ideas which the older psychology postulates, it merely extends this conception in certain directions, giving to the ideas a little more independence, a certain energy in their own right, and a power of existence as psychic objects when one is unconscious of them. Psychology may object to this extension, but the legitimacy thereof can not positively be disproved without rejecting the conception of psychic objects themselves. Hence, we are not surprised to find that many of those who held to the older psychology have given up to the Freudians and have put on their uniform, and that those who have not given up seem to offer a futile resistance. The Freudian propaganda proceeds by leaps and bounds, and Freudian books can not be produced in great enough quantity, nor their prices be put high enough, to fill the demand. The Behaviorists here also are of no help in the fight. There is for them theoretically nothing to fight about, and as a matter of fact the majority of them seem inclined to join the enemy.

The infiltration of psychology by Freudianism proceeds so fast that already much of the established data of psychology has been appropriated and woven into Freudianism in such a way that the rank and file believe Freud originated all psychology. One is informed that no one ever supposed that these were definite causes of mental phenomena before Freud discovered them: it is even implied that the association of ideas was a Freudian discovery: and one who admits that sex has some importance in individual and social thought life is classed by the rabble as a Freudian at once.

The danger from psychoanalysis comes much nearer home to psychology itself than does the danger from mysticism and occultism. Interest is diverted directly from psychological research wherever Freudianism thrives. Experimental work is not encouraged by the Freudians, because they have a schematic

explanation of everything on *a priori* principles. Thus the support and encouragement which the experimental psychologist needs for the promoting of his work tends to be withdrawn where psychoanalysis rears its head as a rival. That this discouragement of, and opposition to, psychology reacts on the psychological arts, many of you know from your own experience.

But even here, I do not wish to stress the interests of psychology itself, but rather to emphasize its duty to general science and to society at large. In the present emergency, men of other sciences look to psychology for light and information concerning the large claims of psychoanalysis. And the light of psychology seems too dim, and its voice is too much enfeebled to carry far into the crowd. Upon us also is the responsibility to protect society from charlatanism and superstition. And if we allow psychology to become merely a synonym for Freudianism, we put ourselves in the position of silly sheep whose clothing the wolves are wearing.

Scientific psychology is the sure antidote for Freudianism because of its three essential characteristics: its empirical basis, its logical method and its fundamental working hypothesis that the fact of consciousness is uniformly connected with reaction. Refusing the *a priori* concept of a world of mental objects, and adopting the empirically given fact of *being conscious,* scientific psychology removes the ground on which the doctrine of "unconscious consciousness" is based; and by emphasizing in its working hypothesis the continuity and common ground of habits of action and habits of thinking, and their essential interrelation, scientific psychology explains the facts of conscious life, whether of waking life or of dreams, without leaving any function for the mystic "unconsciousness," even if one should wish to posit it.

Furthermore, by its insistence on the fundamental logical precaution of using a term only in a definite and uniform sense, scientific psychology destroys the method of procedure which Freudians borrow from the mystics, which method consists in employing the well-known logical fallacy of the ambiguous middle term. Robbed of the easily shifting meanings of *libido, sexual, unconscious,* and the other stock terms, and with the light turned on its *a priori* basis, the Freudian system goes to pieces inevitably.

These needs for psychology which I have been presenting are of a definite, if negative, nature. Psychology is needed to ward off the assaults of definite forces directed against the in-

tegrity of science and the intellectual values in society. But there are other needs, of a positive sort, which unfortunately are less definite although no less important. These needs are more strictly social than the ones we have been considering.

Society is in a state of extreme restlessness. Social problems are perhaps no more pressing today than they have been in every period, but the recognition of these problems is certainly more clear. Our political system is being questioned and attacked. There are those who proclaim in essays, in books and in editorials in our most respectable journals, that democracy is a failure, that the declaration of independence is an absurdity, and that the rights of man are a nuisance. Compared with the feeble efforts of the Bolshevists, these attacks upon our governmental system are enormously more unsettling.

Aside from the shaking of the foundations of government, our whole attitude towards laws, and the making of laws, is in flux. And our conceptions of economic principles and economic ideals are not as firmly fixed as they were. People are seriously questioning the rights of property, so long held sacred, and asking whether it is not necessary for social welfare that these rights should be modified. The question of population is being given a new sort of consideration, and immigration and the birth rate are being made problems dependent upon principles of eugenics and the raising of standards of comfort and culture, rather than matters of religion and pride of magnitude. There is a growing tendency to treat all social problems, including problems of economics and political problems, not as mere matters of blind principle, but as matters for scientific and ethical determination. And men are seeking for light on these problems, and for relief from prejudice, as they have never sought before.

In this situation it is well that we should ask ourselves: What is psychology doing for the advancement of the solutions of our social problems? The answer is—nothing. Most of you perhaps think that psychology can do nothing, and that no responsibility rests upon it. You will undoubtedly agree with me that while clinical psychology and criminal psychology, and allied branches, have great value as sources of ameliatory measures in the conditions which confront us, they offer nothing towards the basic improvement of these conditions. The psychological arts contribute to the solution of our social problems no more than do the mechanical arts or the industrial arts, but rather contribute with these to make the problems more acute.

Where, we ask, is our social psychology? And the answer

is, that it is yet in the making, and that it is being made not by psychologists, but by politicians, and by independent thinkers like Bertrand Russell and Bernard Shaw. And if you ask my opinion, I will tell you that I think it is being very imperfectly made, as we should expect under the circumstances.

We should have a social psychology. Psychology should have something to offer to the world on these problems which are by admission of all so largely psychological. And there is no school of psychology to which we can turn hopefully except that which I have been describing as scientific. The older psychology has acknowledged its impotence. What it offers as social psychology is merely the pleasant diversion of understanding social events after they have happened. But this is not to be charged against that psychology as a crime. Rather, the traditional psychology is to be given the major credit of having led up to the point at which it seems possible that we may, if we carry out the trust it has confided to us, offer a real social psychology.

On this point, as on the others, the more radical psychology, which abandons the parent stem, is found wanting. That which is needed is a social psychology: not physiology. We need to deal with the desires, with the purposes, the emotions, and the conscious tendencies of men and women, and we need to deal with them as they are; not after abstracting from them that which is their important and essential characteristic.

The scientific psychology—empirical: omitting nothing from the facts: assuming nothing as empirical fact—logical: arriving at no conclusions by juggling with terms—proceeding experimentally with working hypotheses—alone offers any chance of finding the help which society needs. And in scientific psychology, treating men as they are, as active conscious beings, without building up around itself a wall of psychic objects, there is real hope. Of this I am firmly convinced, although I can not demonstrate the certainty.

There is, then, great need for scientific psychology, and unless the scientific study of psychology is promoted, in laboratories, and in the field: and unless the teaching of scentific psychology is fostered in the class room, and in print, culture will be impaired, and social progress impeded.

In emphasizing the need of scientific psychology, I repeat, I do not wish to be understood as ignoring the claims of the past to recognition and appreciation. On the contrary: the possibility of a scientific psychology to-day is founded on the work of Aristotle and his successors through the centuries. But I wish

to repeat, that we are false to our predecessors, if, after having received the brand from their hands, we stand still and do not go forward with swift feet.

Again I must insist, that I do not minimize the importance of progress in those psychological arts in which we are so much concerned. But I do insist that there are values for which mental measurements and the other arts do not assume the responsibility, and that the progress and the social worth of these psychological arts themselves are dependent on these other values.

Finally, I must explain, that, however narrowly I may have defined scientific psychology, I stand upon no narrow definition and no rigid test. I believe that in spite of differences of formulation, differences of minor principle, and even differences of purpose, the great body of American psychologists are in spirit united in what I have imperfectly outlined as scientific psychology, and that we shall overcome the dangers to which I have pointed, and will go forward not only to continued scientific achievement, but also to that essential social service which psychology alone can render.

JOSEPH LISTER, HIS LIFE AND WORK[1]

By Dr. PAUL F. CLARK
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JOSEPH LISTER was born on April 5, 1827, the son of Joseph Jackson Lister and Isabella Harris. His father was a London wine merchant of good old Quaker stock and a man of unusual ability. He devoted his leisure hours to the study of optics and was to a degree the founder of modern microscopy in that he was the discoverer of important equations which led to the production of the achromatic lens. Joseph Jackson Lister was largely self-taught and in the midst of an active business life he found opportunity to make his mathematical calculations, to grind lenses himself, and to earn a reputation which gained for him fellowship in the Royal Society in 1832. He was also a good Latin scholar, a skilful artist, and well versed in French and German.

Joseph's mother was a cultivated and beautiful woman of strong character who apparently, however, had less influence on the development of the future surgeon than had his father.

Shortly after his marriage, the elder Lister bought a commodious attractive house with fields and gardens at Upton in Essex. At that time, Upton was only a winding lane with a scattering of comfortable houses instead of a sordid part of busy London as it is now. Forest, marsh and the delightful banks of the Thames made a peaceful rural setting for the boyhood of Lord Lister. Upton was a community of the Friends and there young Lister grew up with his three brothers and two sisters among the rigorous restrictions and in the peaceful isolation of such a group.

BOYHOOD AND EDUCATION UNTIL 1852

Joseph Lister went to two private schools; the first at Hitchen and the second at Grove House, Tottenham. He was rather a precocious, serious lad, especially well versed in the classics because of his training at home with his father. The children used to read Latin classics to the elder Lister while he was dressing. On the whole, however, his amusements were those of an ordinary schoolboy. More than thirty of his early

[1] Paper read before Wisconsin Historical Seminary May 26, 1920.

school papers are still preserved. It is interesting to note that four of these dealt with the human skeleton and one on the similarity of structure between a monkey and a man. At an early age he became interested in natural history, dissecting many small animals and articulating skeletons. While still young he decided to be a surgeon and never deviated from his chosen path.

Lister's religious affiliations debarred him from entrance into the older universities, so after completing his preparatory course at the age of seventeen, he was sent to University College, London, which was distinctly non-sectarian. He spent three years there working for his A.B. in rather gloomy surroundings.

He began his early medical studies in earnest in the winter of 1848, devoting more of his time than does the average medical student to the fundamental sciences, including physics. Lister's introduction to surgery came shortly after the discovery of anesthetics, and although this discovery represents a striking landmark in the history of surgery, the change produced came only gradually. Operations were still performed at high speed and the technique used was the same as found in the pre-anesthetic days.

> At University College Hospital one theatre of modest dimensions containing one small instrument cupboard, a sturdy wooden table, a single gas jet and a solitary washing basin served for every purpose including the novel one of administering the anesthetic.

In following the cases Lister observed that it seemed to be a lottery whether patients recovered or died. Inflammations, suppurations, erysipelas and hospital gangrene were the too common sequellæ of operations. In such surroundings, then, Lister obtained his first impressions of the profession which he had chosen for his life work. His cousin, Thomas Hodgkin, described him as "kind and considerate but rather dwelling apart and not making any strong friendships with his fellow students." But an older member of the group of Friends with whom they both lived spoke of him as one "who in the total excels any one I know, or have known, in bright promise for the future."

When he became a resident in the hospital, he was associated with men of other religious denominations and from other schools and thus began to have a somewhat broader outlook on life and to enjoy the pleasant club life of the hospital interne. He entered with zeal into student politics and the debating society, heading a sharp attack on the homeopaths.

He was granted the degree of M.B. of the University of London and a Fellowship of the Royal Society of Surgeons in 1852 at the completion of nine years at the University College.

During the latter part of his course, he did some original work stimulated by Wharton Jones and William Sharpey, professor of ophthalmic medicine and surgery and professor of physiology, respectively. His observations were published the next year, 1853, in the *Quarterly Journal of Microscopical Science.* The first of these papers confirmed and extended Kölliker's observations demonstrating the existence of two distinct muscles, the dilator and sphincter in the iris. The second paper also confirmed the work of Kölliker on the structure of the involuntary muscle fibers of the skin. These papers are beautifully illustrated with his own camera lucida drawings. These investigations were carried out before any of the modern methods of sectioning and staining were known, but in spite of this, the work is surprisingly well done.

Holidays were not neglected during his student days and these he spent usually with members of his family in different parts of England, Ireland and the Continent. He kept elaborate leather-bound diaries, most of which have been preserved. The style in his diaries is rather stilted and the subject matter not especially interesting. He shows, however, that he was a keen observer of geology and architecture, manners and customs, and that he had acquired considerable facility with French and German. Two sports that attracted him were swimming in the summer time and skating in the winter, although as to the latter he states that he never got beyond the making of figure eights and threes of rather small dimensions.

EDINBURGH, 1853–1860

At the end of his medical course, Lister, having no definite plan in mind, was advised by Sharpey, who had influenced him markedly during his medical course, to visit Syme in Edinburgh for a month and then to make a more prolonged trip to the various continental schools. So in September, 1853, Lister went to Edinburgh, presented his introduction to Mr. Syme, and was received most cordially. Syme invited him to his home, gave him the opportunity of assisting with private operations, and set him to work in the hospital. Lister was surprised to find that Edinburgh was ahead of London in many ways. Syme was at this period fifty-four years of age, in the prime of his work and was, perhaps, the first of British surgeons. He was a pioneer not only in the manner of teaching

clinical surgery but in the wider field of general medical education. There seems to have been a mutual attraction between Syme and Lister and, persuaded by his admiration for Syme and the unusual opportunities offered him, Lister determined to remain in Edinburgh. A month later he was made supernumerary house surgeon and soon afterwards resident house surgeon. This gave him ample opportunity, as Syme seldom interfered with the treatment of ordinary cases and accorded Lister the exceptional privilege of using his own discretion as to which of the cases admitted at night he should himself operate upon. Lister became a frequent visitor at Milbank, where Syme devoted his leisure to his garden and his orchids. There he met famous men from all parts of the world, as Syme was one of the most prominent in this important medical center. In the autumn of 1854, Lister applied for the vacant assistant "surgency" at the Infirmary. Syme promised him his support and also free access to his wards. Accordingly he hired the lecture room and began preparing for the lectures in earnest. Only four months remained before the opening of the winter session and there were many duties and distractions. One of the greatest distractions was Syme's eldest daughter, Agnes, and by the end of July he found he could do nothing more in the preparation of his lectures until the matter was settled. Fortunately it was settled favorably. One difficulty arose, however, in that Miss Syme was not a member of the Society of Friends and Quakers were not allowed at that time to marry "Out of the Society." Accordingly Lister resigned and became a member of the Church of England. This change never seems to have caused him any mental unrest.

The marriage took place at Milbank on April 23, 1856. The young couple spent a month in the region of the English lakes and at Upton and then started on a three months' tour on the Continent. In the course of this trip Lister made the acquaintance of many surgeons, visited most of the leading medical centers of Europe, and greatly improved his facility in the use of the Italian and German languages. In Vienna he met Rokitansky and saw his remarkable pathological museum.

Lister and his wife returned to Edinburgh in October, 1856, and settled in their new home, 11 Rutledge Street. This was not very attractive as to its surroundings, but was near the business houses and well adapted for consultations. He was elected to the assistant "surgency" in October, 1856. The number of students attending his lectures this year was only eight, but he was not at all discouraged. At this time he was

hard at work on his investigations on the early stages of inflammation and some experiments upon the coagulation of the blood. He read a paper before the Royal Society of Edinburgh on December 1, 1856, "On the Minute Structure of Involuntary Muscular Fiber." This again confirmed and extended some observations of Kölliker. During the early part of 1857 his letters refer to the excitement of his first public operation at the Infirmary and to the beginning of his private practice. He was delighted with his work and in a letter to his mother his attitude is shown by the statement that "fearing as I am sometimes apt to do that a mode of life so much in accordance with my tastes as mine now is must be too pleasant to be proper for me." In a letter to his father, February 26, 1857, he describes his feelings at his first operation:

> Yesterday I made my debut at the hospital in operating before the students. I did two operations in the presence of a very full theatre and several surgeons and old practitioners. I felt very nervous before beginning, but when I got fairly to work this feeling went off entirely, and I performed both operations with entire comfort. And I also explained the operations and cases to the students without embarrassment. Altogether I felt very thankful at the way I was able to acquit myself. Everybody congratulated me afterwards and the students cheered me very warmly.

In June, 1857, he read an important paper on the early stages of inflammation. He made the observations for the most part on the frog's web, although he also used the bat's wing in order to utilize a warm-blooded animal. He describes very clearly the vascular changes in early inflammation, using a great variety of irritants such as hot water, mustard, etc. He apparently never detected the migration of white blood corpuscles, which was due probably to the fact that each experiment extended over a very short period of time. Cohnheim, to whom the credit is usually given for the earliest observations on the microscopic changes in inflammation, did not publish until ten years later, 1867. As a matter of fact, credit really belongs to neither of these men, but to William Addison (1843) and Augustus Waller, who made careful observations in 1839, although he did not publish until 1846.

In the summer of 1858 he started another course of lectures dealing with surgical pathology and operative surgery. His desire to give his students the fundamental facts of physiology led him to work still further on the coagulation of the blood. In his collected papers are five dealing with this subject.

During all this period Lister worked most industriously, frequently far into the night, on his experiments. Mrs. Lister

assisted him greatly, taking his dictation and aiding him with the details of his work.

Lister's private practise was growing, largely through the influence of Syme, and he was enjoying the increased prestige of his position. He was looked upon as a young surgeon of great promise and a first rate investigator. In August, 1858, the professorship of surgery in the University of Glasgow became vacant and Lister was urged to apply for the position. It was a regius professorship, and although there was considerable difficulty and vexation due to politics, Lister's appointment was finally made on January 28, 1860. The seven years in Edinburgh were accordingly brought to an end with much regret on the part of Lister, his students, and colleagues.

Glasgow, 1860–1869

The appointment at Glasgow offered a wider opportunity for his powers than could possibly have been the case at Edinburgh at that time. In Edinburgh he was somewhat overshadowed by the strong personality of Syme, whereas in Glasgow he was now thrown upon his own resources. For the first year he was without any hospital appointment, but had plenty of private practise and came into close association with many congenial colleagues. His induction into office involved the presentation of a Latin thesis which he sat up practically all night to write and finished on the train from Edinburgh to Glasgow. This was a common habit of his. There were always many demands upon his time, and he never allowed himself time enough to write his lectures or prepare for the extramural functions that were a part of his duties. He was not given to punctuality. The matter at hand was always of greater importance than the duty of the future.

The first lecture of the winter session at Glasgow was on the importance of surgery.

> He dwelt on the value of anatomy and physiology to the surgeon and amongst other surgical matters, on the importance of making serviceable stumps which he illustrated by a case of amputation of both legs in which his patient was still able to dance the Highland Fling.

The number of students in his class finally reached 182, probably at that time the largest class in systematic surgery in Great Britain. The students became very enthusiastic, made him honorary president of their medical society, and backed him in his claim to the "surgeoncy" of the Infirmary with 161 signatures. He was finally appointed surgeon to the Royal In-

firmary on August 5, 1861. In all his teaching, whether in the form of lectures, demonstrations, or the correction of student papers, he was exceedingly conscientious. In correcting examination papers, every point in an answer to a question was given its percentage value and the papers were graded with painful precision.

In spite of daily lectures and the pressure of private practise, he published at this time an important paper on the excision of the wrist for tuberculosis, which extended his reputation very considerably.

In September, 1864, Lister's mother died. The parents had been living alone at Upton for the previous six years and after the death of his wife Joseph Jackson Lister passed the remaining five years of his life in lonely isolation. His son, Joseph, from this time on, wrote a weekly letter to his father, and it is from these letters that we gain much information in regard to the daily life, ideals, work and ambitions of Lister.

In order the better to understand his most important work, namely, Lister's discovery of the principles of antiseptic surgery, it will be necessary to suggest briefly the conditions that prevailed in hospitals. At that time there was no security that the simplest operation would not end in a fatal septicemia. In Glasgow and in fact in all the cities, wards were not infrequently closed for a time on account of the frightful mortality. In Nuremberg the hospital authorities seriously considered the pulling down of the Allgemeines Krankenhaus. Microbes were looked upon as scientific curiosities, the hospital diseases, erysipelas, pyemia, septicemia, hospital gangrene, and tetanus were often called septic, but no one realized what that meant. "Surgeons were fighting all of these diseases in the dark or submitting to them as inevitable." These were the days of "laudable pus" and the common assumption was that putrefaction and purulent infections were due to the oxygen of the air.

Surgical cleanliness as understood at that time would astonish a modern observer. In the institutions that had felt the influence of Florence Nightingale, the nurses indeed were fairly neat and esthetically clean.

> But no such attempt to satisfy the proprieties was made by the surgeon and his assistants. When a dresser or a house surgeon entered upon his term of office, he hunted up an old coat in the lapel of which he probably carried a wisp of ordinary whipcord for tying arteries. This garment did duty for six months or a year and was then very properly discarded. There were no such time limits, however, for the surgeons themselves. Their operating coats lasted from year to year and event-

ually acquired an incrustation of filth of which the owners appeared unconscious or even proud. This set the tone and some who were then young can remember the scorn with which they were greeted when in their reforming zeal they broke away from ancient custom, boldly took off their coats and operated with upturned shirt sleeves.

No attempt was made to isolate septic cases; nurses and dressers passed directly from erysipelas wards to healthy patients. Lister complained that in Glasgow the closets communicated directly with the wards. The supply of water even in the operating theaters was inadequate and one of the frequent duties of the operating surgeon was the performing of postmortem examinations. As in Vienna in the time of Semmelweis, the surgeon used frequently to come from the postmortem chamber directly to the operating room, with only such cleanliness as common decency demanded. Surgeons were not ashamed to speak of a "good old surgical stink."

The mortality statistics after amputation gives some indication as to the prevailing conditions. At the Edinburgh Infirmary the death rate was 43 per cent.; at Glasgow Infirmary 39.1 per cent. At the Pennsylvania Hospital the record was unusually good, the average mortality for a series of years being 24.3, while at the Massachusetts General Hospital, the average was 26 per cent. The mortality in the French Hospitals was even greater than that in London, amounting to about 60 per cent. Billroth at Zurich reported a mortality of 46 per cent. Sir James Simpson, the discoverer of chloroform anesthesia, stated "that the man laid on the operating table in one of our surgical hospitals is exposed to more chances of death than the English soldier on the field of Waterloo."

The cause of these conditions was unknown; doubt and uncertainty existed in the minds of all. A polluted atmosphere was the generally accepted cause, although opinions differed as to how the air became tainted. The work of Semmelweis (1861) had made no impression and it remained for Lister to rediscover and extend the observations of this martyr to science.

In handling open wounds at this time, two general lines of treatment were followed. One was to encourage the formation of a scab. After the edges of the wound had been approximated, no dressing was applied, but sometimes certain powders or caustics or a piece of lint soaked in compound tincture of benzoin. The other method was known as the open treatment. The edges of the wound were allowed to remain quite open and a piece of linen protected it somewhat from flies and dust.

Some carried the first method to the point of what is called the "occlusion method." Collodion was used, completely excluding the polluting air. The occlusion method obviously did not allow the drainage of pus, so Syme adopted what he called a dry dressing. Lister pointed out, however, that this very soon became a moist dressing due to the discharge from the wound. Water dressings and bread and linseed meal poultices were in common usage in some of the hospitals. Ligatures were of silk or whipcord drawn over beeswax. Usually one end was cut off short and the long ends of several ligatures gathered together for drainage. With the progress of the purulent inflammation which so commonly occurred, the ligatures were sloughed off and secondary hemorrhage was common.

One more point deserves attention, namely, "subcutaneous" surgery, by which was meant the performance of a minor surgical operation through a puncture so small that little air was admitted. The fact that these operations were so commonly free from putrefaction was held to be due to the fact that air was not admitted to the wound.

It was under such conditions as these that Lister taught and worked, his technique being no better than that of many others. There was this difference, however: he did not believe these conditions inevitable, and he was constantly searching by observation and experiment to find out the cause of the high mortality in all hospitals.

Sepsis was known at the time, though the cause was unknown and the word "antiseptic" occurs in medical literature as early as the middle of the eighteenth century. Many antiseptic substances had been used from the time of the early Egyptians and doubtless before that. At the time of which we are writing, alcohol was freely used on the continent and it was of course the basis of all tinctures. The good Samaritan poured in "oil and wine." Glycerine was used in England, especially in cases of hospital gangrene. Chlorine and its compound, chlorinated soda, and chlorinated lime were early recognized as powerful antiseptics. Iodine was discovered in 1811, was used for a while, and then went out of fashion. In 1815 the antiseptic properties of coal-tar products were known in France and carbolic acid was discovered by Runge in 1834. As early as 1851, Calvert, an English chemist, used carbolic acid for the preservation of cadavers. Jules Lemaire worked extensively with carbolic acid and published in 1860 and again in 1863. Carbolic acid in the treatment of wounds and sores became the fashion in France for a while. All of these anti-

septics were used, however, not with the hope of preventing the occurrence of putrefaction, but with the aim of neutralizing its effects after it had developed. The two exceptions to this rule were Semmelweis in Vienna and possibly Lemaire in Paris.

In 1865, while intensely occupied with the study of suppuration, Lister learned from the work of Louis Pasteur that putrefaction was a kind of fermentation caused by the growth of microorganisms and that these microorganisms were present in the dust of the air and responsible for wound infection.

The enormous significance of the work of Pasteur was immediately apparent to Lister, who had for so many years been struggling with this problem. Since the cause of suppuration and septicemia was now known, it was obvious that the prevention of such infections depended upon keeping the causative organisms away from the wounds. His attitude can best be understood by quoting from one of his papers published in 1867.

> In the course of an extended investigation into the nature of inflammation and the healthy morbid conditions of the blood in relation to it, I arrived several years ago at the conclusion that the essential cause of suppuration in wounds is decomposition, brought about by the influence of the atmosphere upon blood or serum retained within them and in the case of contused wounds upon portions of tissue destroyed by the violence of the injury.
>
> To prevent the occurrence of suppuration with all its attendant risks was an object manifestly desirable; but till lately apparently unattainable, since it seemed hopeless to attempt to exclude the oxygen, which was universally regarded as the agent by which putrefaction was effected. But when it had been shown by the researches of Pasteur that the septic property of the atmosphere depended not on the oxygen or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air by applying as a dressing some material capable of destroying the life of the floating particles.
>
> Upon this principle I have based a practise of which I will now attempt to give a short account.

His notion then was much more like that of aseptic surgery than is generally conceded. He likened our skin to the glass of Pasteur's flasks. In a compound fracture the bottle is broken and the air with the attendant bacteria gain access to the tissues below. To be sure he paid more attention to air as a source of infection, although he recognized that his hands and open wounds were also infected.

In considering the possible methods of eliminating the airborne infections, he chose chemical antiseptics as his means and happened to hit upon carbolic acid first. The first product

used was a crude acid known as German creosote, which he tried on a compound fracture.

Quoting from one of his papers,

> After cleansing the broken limb and squeezing out as far as possible all parts of blood, a piece of calico or lint soaked in undiluted carbolic acid and held by a pair of forceps, was introduced into the wound and passed freely in all directions in order to destroy the germs that had entered either at the time of the accident or afterwards and might be lurking in deeper parts. A piece of lint similarly soaked in the acid was then applied to the wound just large enough to overlap it in every direction by half an inch. This was covered by a slightly larger piece of thin block tin or sheet lead, the object of which was to prevent the evaporation of the antiseptic. The dressing was then fixed in position by strips of adhesive plaster and some suitable absorbent material was packed around between the limb and the splints for the purpose of soaking up any blood or discharges that might escape. The blood and carbolic acid soon formed a tenacious crust or thick paste which was not removed for several days but its antiseptic properties were renewed from time to time by painting some more of the undiluted carbolic acid on its outer surface after removing the metallic plate for the purpose.

He found that the crude acid caused necrosis and sloughing, so he next used a 5 per cent. watery solution of a purer product which he succeeded in getting and a higher concentration in linseed oil. This last was too irritating, so after repeated attempts he used a putty made with calcium carbonate and a solution of phenol in linseed oil, one part in four or one part in six. This did not irritate the skin or tissues greatly. He constantly reiterated that the ideal dressing should be mild and non-irritating and he continually advanced as his ideal the establishment of conditions in compound fractures and open wounds similar to those that obtained where the skin is unbroken. He did not obtain another suitable case for the application of his principle until the spring of 1866. This also was a compound fracture and he wrote his father on May 27:

> It is now eight days since the accident and the patient has been going on exactly as if there were no external wound, that is as if the fracture were a simple one. His appetite, sleep, etc., good, and the limb daily diminishing in size while there is no appearance whatever of any matter forming. Thus a most dangerous accident seems to have been entirely deprived of its dangerous element.

He published his epoch-making observations in several sections in the *Lancet* between March and July, 1867. Only one out of eleven cases died (although one had lost his leg), an almost unheard of success, especially under the abominable conditions that prevailed in the wards of the Glasgow Royal Infirmary.

From this time he continually strove to improve his tech-

nique, trying many different antiseptics and working with intense zeal on each case that came to his wards.

Lister claimed to have discovered a new principle necessitating fundamental changes in the conception of the causation of infected wounds and therefore in the treatment of these wounds. This claim was received with incredulity on the part of some, open resistance on the part of others, and apathy on the part of most persons. Unfortunately the nature of his discovery was from the first confused with the discovery of carbolic acid, and when it was made clear that carbolic acid had been used for years many considered Lister's claims palpably false. Sir James Y. Simpson led the attack on Lister in Scotland, and an anonymous letter in the *Edinburgh Daily Review* made it appear that all Lister had done was to reproduce in Great Britain what had long been the continental practise. The controversy waged rather bitterly at times and Lister suffered keenly from mortification. Attention had been directed to the use of carbolic acid and not the fundamental underlying principle, and in spite of all Lister could do, the phrases "carbolic treatment" and the "putty method" were on every one's lips. Simpson gave all credit to Lemaire and because of his extended reputation, this point of view became widely disseminated. Lister's chagrin can well be imagined, but in this short paper we can hardly afford the time to quote from his published letters on this subject. Very wisely he did not allow himself to be drawn deeply into the controversy, but continued his efforts toward the improvement of his technique, and in open lecture and published paper continually reiterated that his discovery was a fundamental principle and not a new method of dressing.

His successful treatment of cases continued. Visitors from other countries as well as from near by came to his wards for purposes of observation. Those who came and actually saw seem to have been well satisfied, and year by year his teaching was spread by his own students as they passed out to new fields of endeavor. He no longer used strong carbolic acid, but found a 5 per cent. solution adequate. Even at this time he was trying to dispense with antiseptics. He states:

> Of all those who use antiseptics in surgery, I expect that I apply them least to the surface of the wound.

At this time also he was attempting to find a suitable "protective," a non-stimulating substance impervious to carbolic acid; varnished oiled silk was his final word in this direction.

Secondary hemorrhage was a continual source of danger in

the septic wounds of that day and Lister was the first to recognize why the ligatures sloughed away from such a wound. He did much experimental work in attempting to find a ligature which should be strong enough and yet capable of being digested finally by the fluids of the body. Silk ligatures soaked in strong carbolic for two hours, catgut ligatures soaked in a great variety of disinfecting solutions, were used one after another. His final process in 1908 was the use of chromium sulphate and corrosive sublimate as a means of disinfecting well-seasoned catgut. This and several other methods of treating catgut devised by Lister are still in use to-day.

In the spring of 1869 Syme had a paralytic stroke and in the summer he resigned his chair, urging Lister to become a candidate for it. A large number of the Edinburgh students sent a delightful letter to Lister urging his candidacy and on August 18 he received news of his election to the Edinburgh professorship. A month after this appointment Lister's father, almost eighty-four years old, was taken ill and shortly afterwards died. For Lister, this meant a deep personal loss and led to the breaking up of the old home at Upton.

EDINBURGH, 1869–1877

The Listers moved to Edinburgh in October, 1869. He settled at No. 9 Charlotte Square in one of the most fashionable parts of the city and had to pay what he called "a most enormous sum" for it. His private practise developed very rapidly, his lectures were largely attended by an enthusiastic group of students and he was delighted to find his expectations realized in that his life was not as tied up with routine as at Glasgow. His university duties were considerably less, inasmuch as he gave only two clinical lectures a week, instead of the daily lecture in systematic surgery. He also enjoyed the fact that his hospital visit occurred at noon in Edinburgh instead of the early morning as at Glasgow.

He found many changes in Edinburgh from the conditions that had prevailed ten years before. Syme and Simpson, the two strongest personalities, were both nearing the close of their active lives. Syme indeed died in June after Lister's return to Edinburgh. He mourned the loss of Syme very deeply. The relation between the two had been almost that of father and son. Lister had always trusted much in Syme's advice and in his judgment, but with the death of Syme, Lister stepped into the first place among the surgeons of Scotland.

Lister began again to devote more of his time to investigations and bedtime was frequently postponed until four or five o'clock in the morning, while he made careful notes or delicate camera lucida drawings. His hospital visits occurring at noon caused the noon-day meal to be decidedly a movable feast. Each antiseptic case received his personal attention, and the assistants frequently became very hungry while their "chief" attended to details which seemed to them very minute. The classes were large, sometimes numbering 170 to 180, and the lectures, judging from the reports of his students, were intensely interesting. He no longer spent hours in preparation for his lectures, but perhaps half an hour sitting quietly in his armchair, thinking.

His laboratory work for the next few years was largely bacteriological in character. Four or five hundred closely written foolscap pages with many careful drawings in what he called his "common-place" book give evidence as to the large amount of time spent in bacteriological work. Altogether he published six papers dealing with bacteriological subjects, no one of which gives evidence of observations of lasting importance. They did, however, bring him into touch with Louis Pasteur and the correspondence between the two is delightfully interesting.

Two modifications of his surgical technique were introduced during the early years of his second Edinburgh period. The first was the carbolic acid spray, about which so much has been said in open ridicule and the second the use of absorbent gauze dressings. Pasteur's teachings, it must be admitted, strongly favored the air-borne theory, and there was at that time no clear-cut distinction between pathogenic and saprophytic organisms. In the use of the carbolic spray, Lister allowed his theorizing to lead him away from his experimental basis. In this period of his work it seems to me that he rather neglected his earlier fundamental conceptions, becoming infatuated with carbolic acid as a panacea. So in the minds of many the term "carbolic acid treatment" was superseded by the "spray and gauze treatment." Lister's notion was that the spray would mechanically cleanse the air and destroy the bacteria present. The machine for the production of the spray passed through a regular evolution from a small hand atomizer, to a foot spray worked with a bellows, to a cumbersome tripod machine worked with a long handle which bore the name of "the donkey engine" among the scoffers and finally to a beautifully designed machine producing a steam spray. The spray

was used in many parts of the world for years, although doubts arose in the minds of many and finally Bruns of Tübingen (1880) condemned it in a forceful paper entitled "Fort mit dem Spray." Lister finally abandoned the spray in 1887, acknowledged that its use had been based on a misconception of the facts, that pathogenic organisms were not very plentiful in the air, that it was extremely irritating to the hands of the operators, and that the air was not, after all, the principal source of wound infection. At the International Medical Congress at Berlin in 1890, he states:

> As regards the spray, I feel ashamed that I should ever have recommended it for the purpose of destroying microbes in the air.

The substitution of the gauze dressing for the plaster was a distinct improvement in Lister's mind, because it made the antiseptic treatment easier to carry out. Many different antiseptics were used to saturate the gauze and a great deal of experimentation was carried out to test each one. Oakum dressings, carbolic gauze, gauze soaked in corrosive sublimate, the double cyanide of zinc and mercury, all the different common salts of mercury, many volatile disinfectants, sero-sublimate gauze, and boric acid all passed through various stages of trial in his laboratory and wards. Several papers in this field were published in the *British Medical Journal* and the *Lancet* in the years from 1884 to the end of his active life as a surgeon.

The story of the gradual spread of Lister's teachings need hardly be recorded save in the briefest form. The controversy was waged and there were those who scoffed, but for the most part the junior physicians and surgeons everywhere were beginning to swing towards Lister's point of view. Among those on the continent who became his adherents must be mentioned Ernst von Bergmann, who became convinced that the antiseptic method was only a stage in the development of surgical technique and that the aseptic method must be the treatment of the future. He became the apostle of aseptic surgery and was instrumental in the general hospital improvement that dated from this period. Lister's teachings were accepted more rapidly in Germany, Switzerland and Scandinavia, than in England. Of the foreign countries France was especially slow to take up the modern methods.

During these years at Edinburgh his published papers were numerous. No less than ten connected with antiseptics and two on fermentation appeared between 1870 and 1876. During the Franco-Prussian War his hope that antiseptic methods

would lead to more adequate control of infected wounds was only partly realized.

In 1875 he made an extended continental tour with his wife and other members of his family. The first part of the trip, spent for the most part in Italy, was largely for pleasure, whereas the latter part, through the university towns of Germany, was a triumphal procession. He was dined and wined by physicians and students who welcomed him as the forerunner of modern surgery.

They returned to Edinburgh toward the end of June and immediately afterwards he took the first of many trips in opposition to the work of the anti-vivisectionists. This group of misguided sentimentalists became extremely active in England and, in spite of the opposition of Lister and other leaders in medicine and the biological sciences, put through a "cruelty to animals act" in Parliament which has hampered the efforts of experimenters in that country even to this day. Lister's letter to the Queen opposing the "cruelty to animals act" is a model of courteous but strong opposition to the restriction of well-handled animal experimentation. The law as passed forbids any experimentation save in a registered house by licensed investigators.

> It forbids the granting of a special license to a distinguished doctor to experiment on a chloroformed frog in his own study in pursuit of science, while it allows any one who can afford it to hunt a stag to death or set two greyhounds to chase a hare and wager money on the result.

In September, 1876, Lister, together with Mrs. Lister and his brother, attended the International Medical Congress at Philadelphia. Lister was made president of the Surgical Section, taking a prominent part in many of the debates. He traveled extensively both before and after the congress, visiting Montreal, Toronto, Niagara, going as far west as San Francisco.

In 1877 a chair of clinical surgery was created for Lister at King's College, London, and in spite of the vehement opposition of his students, Lister accepted it.

It is perhaps difficult to understand why Lister should have wanted to leave his preeminent position in Edinburgh, with his well-trained assistants in a hospital dominated by him, where he had large classes of enthusiastic and affectionate students and friends of long standing. But he left these desirable conditions to accept the position at King's College with a comparatively small London hospital, where the average class was less than 25 and where apathy or distinct opposition must be met daily. His primary reason for making the change was that

London was the only city of any prominence that had not adopted his procedures. He felt that he must carry the gospel to the Romans. He was a man with a mission.

London, 1877–1893

In London the Listers lived at No. 12 Park Crescent, well away from the fashionable quarter and also remote from the recognized consultant's quarter, but near the Park Square Gardens and also the Botanical Gardens, and that was what Lister desired. He did not build up a large private practise in London. This was partly due to his lack of punctuality, and partly to his preference learned from Syme of leaving the amount of his fee to the patient's decision. This always placed the consulting physician in rather an embarrassing situation. He also did not wish to leave the after care of his patients to the physician consulting him, who usually had no notion as to Lister's methods. But he had just about the amount of practise he desired; patients were sent to him from all parts of the British Isles. He enjoyed immensely the personal relation established in private practise, taking the keenest interest in the affairs of his patients, and they in turn regarded him with veneration. He would have vigorously opposed our full-time clinical professorships just as at that day he opposed the notion that the professor of pathology should not have beds in the hospital.

He brought with him from Edinburgh four men to form the basis of his staff in King's Hospital. Without the assistance of these well-trained men he would have found it extremely difficult to do anything in the uncongenial atmosphere of King's College Hospital. With the nursing department, there was continued friction. The Sisterhoods were bound by their own notions and inflexible rules. His assistants, Watson Cheyne and John Stewart, tell of several amusing and almost tragic instances of the absurd obstinancy of the Sisters in charge.

One feature of Lister's methods of treatment is worthy of note in that it brings out Lister's great personal interest in his cases as well as the difficulties with the nursing organization. Chronic cases of tuberculosis of the bone, psoas abscesses, etc., which formerly were almost always fatal, became curable, but only with prolonged and careful treatment, so that some cases remained in the hospital for a long period of time. In October, 1877, the managers of the Edinburgh Royal Infirmary decided to discharge some of these chronic cases which Lister had left behind. One woman, Lizzie Thomas, came to London, as Lister

wished her admitted to King's College Hospital. She was brought by the Scotch head nurse in a basket such as were used to move patients in the Edinburgh hospitals. In spite of the fact that it was a cold bleak October morning, the basket and its contents were placed on the floor, while the Sisters insisted that the patient could not be admitted till the secretary arrived two hours later to draw up the regular papers for admittance. Not till Lister's assistant, John Stewart, threatened to put Lizzie to bed himself, with the assistance of the Crimean veteran porter, did the shocked Sisters reluctantly consent to take charge of the patient before all the usual formalities had been observed. In spite of her ungracious reception the patient recovered, as did the other six chronic cases whom Lister sent, at his own expense, to a nursing home, after they had been summarily discharged by the Edinburgh Infirmary.

He attempted to introduce the ward methods of teaching surgery that he had used in Edinburgh, but there were very few cases and the students were apathetic. Lister's classes remained small. Coaching classes were the order of the day and the London examination system which Lister vehemently opposed gave no power to the professor in charge of the course. Students found that Lister's views were not acceptable to the examiners, so they avoided his clinics, and instead of the 400 eager students as at Edinburgh, his lectures were attended by a bare dozen.

Gradually, however, the successful cases made an impression even in London and his lectures began to attract a few general practitioners and a goodly attendance of foreigners.

During his London period, Lister gave many addresses and attended numerous medical congresses. He was a juror at the University Exhibition at Paris in 1878 and seized the opportunity to become more familiar with Pasteur and his work. At the sixth International Medical Congress in Amsterdam, a great reception was tendered him, the ovation at his entrance lasting for some minutes. The seventh International Medical Congress met in London in 1881 and was a memorable occasion. Virchow, Volkmann, Pasteur, Billings and Huxley gave general addresses. The most remarkable paper at the meeting was given by Pasteur on "Vaccination in Relation to Chicken Cholera and Splenic Fever."

For fifteen years Lister occupied the chair of clinical surgery at King's College. His private duties were numerous and his public life became more and more complex. He received honorary degrees and various orders of merit from different

ruling monarchs. In 1883 he was made Baronet. His life in London, however, was less strenuous than that in Edinburgh. Experimentation went on as before and the "Commonplace book" is full of experiments on catgut, gauze, and various germicides. London was finally won over by the pertinacity of Lister and the gradual piling up of facts. Even the *Lancet* published laudatory remarks. He played more and more a leading part in public affairs and in medical education. He always opposed the admission of women to medical schools.

All this time, Pasteur had continued his remarkable studies on the production of active immunity by the introduction of attenuated organisms until one after another the diseases of chicken cholera, anthrax and finally rabies were rendered, if not harmless, at least less dangerous to man and other animals. In order to aid the work in the preventive treatment of rabies the Institut Pasteur was founded and for a number of years it was necessary to send all persons in Great Britain who needed treatment for this disease to Paris. Feeling that this condition should be rectified, Lister and others of the medical profession attempted to establish a similar institute in Great Britain. In spite of much opposition on the part of the anti-vivisectionists the British Institute for Preventive Medicine was established on June 5, 1891. This Institute, finally renamed after Lister, has gone through many vicissitudes but is still fulfilling the purpose of its founders.

As Lister's duties became less burdensome owing to advancing years, his vacations became more numerous and longer, although he never neglected this part of a normal life. He traveled widely, frequently making some medical congress the excuse for the trip. He visited Norway after the Amsterdam congress in 1880, visited Spain repeatedly, had an interesting trip through the Dolomites in 1881 and attended the International Medical Congress in Berlin in 1890. During all his vacations he spent much of his time in the open; he was devoted to fishing and was always interested in field botany. Many of his botanical trips were made with his brother Arthur, who later became an authority on the Myxomycetes. During the latter half of his life, Lister became an ardent follower of Audubon, and could frequently be seen, when on his vacations, with a vasculum over one shoulder and a bird glass over the other.

One of the most dramatic occasions of this period of his life was the Pasteur Jubilee celebrated at the Sorbonne on December 27, 1892. After the opening speeches by the president of the republic and the dean of the section, Lister was called upon

as the representative of the Royal Society of London and the Royal Society of Edinburgh. His address is a delightfully enthusiastic appreciation of the work of the great Frenchman. At the close of the speech,

Monsieur Pasteur se lève pour embrasser M. Lister. L'étreinte de ces deux hommes était comme la representation vivante de la fraternité de la science dans le soulagement de l'humanité.

During the usual spring holiday in the next year, 1893, Lord and Lady Lister (for he had now been made a peer of the realm) went to the Italian Riviera. After about a week of botanizing, Lady Lister suddenly developed an acute pneumonia which resulted fatally.

Lister was now a solitary man. They had had no children and he and his wife had been intimate sharers of their mutual joys and sorrows for thirty-seven years. She had always entered keenly into his scientific work and the numerous "commonplace books" in which are recorded his many experimental observations are largely in her handwriting.

The year before his wife's death Lister had been retired at the age of sixty-five from the professorship at King's College, but his duties at the hospital continued through 1893. At the end of that session he ceased his work in the wards and also terminated most of his private practise. He was still mentally and physically vigorous but the death of his wife and the cessation of his regular duties depressed him very greatly.

Declining Years, 1893–1912

With the death of his wife social gatherings at Park Crescent came largely to an end and he seemed to have no zest even for his experimental work. To give him some regular occupation his friends obtained for him the foreign secretaryship of the Royal Society in November, 1893. He held this position until 1895, when he was elected president. His life for the next four or five years consisted of his duties in this society, officiating at many public ceremonies, and serving in the upper house of Parliament. A number of interesting general addresses date from this period of his life.

In the autumn of 1897 Lister again visited America on the occasion of the annual meetings of the British Association for the Advancement of Science at Toronto and the British Medical Association at Montreal. Following the public ceremonies, Lister and his companions made a tour of the west, taking in Vancouver, Seattle and Yellowstone Park,

Dogs brought up on a diet restricted to two or three articles will, if they are more than a year old, always refuse at first when an entirely new food is offered to them. They base this refusal on the sense of smell and if the meat is putrid enough so that the putrefaction smell completely hides the native smell of the meat then the dog has no objection. In other words, all rotten meats taste and smell substantially alike and are, therefore, recognized as a familiar diet, while any new kind of fresh meat offends the dog through its strange smell.

It is commonly said by hunters and natives who have noticed that dogs will not eat wolf or fox meat that dogs object to cannibalism. I find that the objection of a dog to wolf meat is no stronger than his objection to duck meat or caribou meat, provided that the duck or caribou is an absolutely new meat in the experience of the dog.

I have found that the food prejudice is stronger the older the dog, and I incline to the belief, although we have not a sufficiently large number of experiments to be certain, that with dogs of a given age the prejudice of the female against new food is stronger than that of the male. This seems to strengthen the position of those who believe that women are more conservative than men by showing that conservatism as a sex character is fundamental and extends down into the lower animals.

I have thought that it would be exceedingly interesting to make further experiments in the food tastes of dogs along the following lines:

Newborn pups of the same litter should be selected, one to be fed for two years on mutton and water, another on fish and water, a third on beef, and a fourth perhaps on a vegetarian diet. It would make the experiment more interesting if a male and a female could be used for each sort of diet. Judging from our experiments, it seems probable that at the end of two years the mutton-fed dog would refuse both beef and fish, and the fish-fed dog would refuse both mutton and beef. I believe it would also be found that the abhorrence for the new diet would be stronger with the female in each pair than with the male.

It is well known that some Eskimo groups eat either no vegetable food at all or else practically none. But in all parts where we have been except in Coronation Gulf they are fond of the berry known in Alaska as the "salmon berry" (called in Labrador: Baked apple). We were, therefore, astonished, especially my Alaska Eskimo companions, when we found that the Coronation Gulf Eskimos live among an abundance of these berries and have never thought of tasting them. On inquiry we found there was no taboo against the berries and my Eskimo

companions tried to introduce the fashion. They found no difficulty in getting children to try the berries, except that in some cases the mothers were offended and considered it quite improper for my companions to try to induce children to eat this unheard-of food. The grown men were commonly willing to taste the berries and I do not recall that even one man refused, but I should say that fully half the women positively refused even to taste the salmon berry during the summer we spent with them. This is really a rather good fruit and I have no doubt that by now most or all of the people are eating the salmon berry, but our observation that first year indicated clearly the greater conservatism of the women. We observed this conservatism in many other things—for instance, smoking. Although all western Eskimo women use tobacco and although there have been tobacco-using women on our ships when we have come in contact with these eastern Eskimos, we have always found the men far readier than the women to learn smoking.

I looked into the matter of whether the reluctance of the women to smoke, or to eat salmon berries was due to the idea that things proper for men might be improper for women. It did not seem that any such consideration applied.

I have had a great deal to do with the food prejudices of white men in connection with introducing them to a diet of meat only. I have found that the laws of food prejudice as deduced from dogs have applied to my white companions exactly. Other things being equal, the older the man the more he has objected to trying a new kind of food and to abandoning the foods he was used to. We found with dogs that one brought up on a ship and used to a great variety in diet would take readily to a new diet. Similarly we have found that "well-brought up" men, used in their homes to a large variety of foods, both domestic and imported, take very readily to any new thing (such, for instance, as seal meat). But men "poorly brought-up" and used only to half a dozen or so articles of food in their regular diet, are generally very reluctant to try a new food unless it has been represented to them in advance as an expensive or specially delicious thing. Of course, the situation here is not so simple as it is with dogs. For one thing, the man of the laboring type has a feeling of being degraded when he is compelled to eat the food of "savages," while a man of the intellectual type is appealed to by the mild flavor of adventure in experimenting with "native" food.

THE SCIENTIFIC SELECTION OF MEN

By ARTHUR FRANK PAYNE

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THE problem of selecting men for certain jobs and positions always has been one of vital importance both to the men and to the position. At the present time this problem is increasing in importance and is becoming difficult and complex because of differences of opinion in regard to the method and technique of making a selection of certain men for certain jobs, positions or types of work.

The new science of psychology has standardized certain scales, measures and tests for measuring general intelligence. The best known of these are the "Binet-Simon Scale for Measuring Intelligence." This scale has been revised, the revision being known as the "Stanford Revision of the Binet-Simon Scale."

The army psychologists during the recent war formulated and standardized the well-known "Alpha and Beta" tests for measuring the mental intelligence of large groups of men of varying degrees of education. It was found during the war that units made up of men of equal intelligence were much more effective than when men of unequal intelligence were placed in the same unit. It was also found in certain types of work and units such as artillery, signal corps, engineering corps, medical corps, etc., that a certain standard of intelligence was necessary before any individual could hope to be effective in that particular type of work. Our fighting army was rendered much more effective by this type of testing, selection and placement. There is no good reason why our working army in times of peace could not be made much more effective by the same methods.

Psychologists are now working upon scales and measures for testing the aptitudes of individuals for certain types of work. They know that people who possess certain special abilities are more successful on certain types of work than those that do not possess these certain abilities. They also know that people who possess certain disabilities can never hope to be successful on some particular types of work. This field is known as the "Psychology of Special Abilities and Disabilities."

The army psychologists also worked out tests for the measuring of trade knowledge and trade skill. These were very

effectively used during the war in choosing the men for the large proportion of technical positions now required in a modern army.

All of the above tests, scales and measures are based upon accurate scientific data. The tests have been furnished and standardized by using the same scientific methods that are used in any other branch of scientific research. There is no question about the validity of these tests and without doubt great advances will be made along these lines in the next few years.

The demand among industrial leaders for tests of these types to help solve the labor problem of industry has been so great during the last five years, that it has brought about a revival of the old abandoned so-called science of phrenology, physiognomy, character reading and character analysis. This revived pseudo-science has many followers among industrial executives, and the purpose of this article is to discover the validity of the technique and methods of this alleged science. If there is anything good in it, it most certainly should be recognized and made use of. If it is based upon fallacious assumptions, this fact also should be known.

Phrenology was founded and formulated before any of the recent startling discoveries of modern science were dreamed of. In 1815 Gall of Vienna coined the name phrenology and was its modern progenitor. In America the system was expounded by Caldwell, the Fowler Brothers and S. R. Wells; in England by Spurzheim, Combe and Elliotson. The scheme as founded by Gall is to inspect the scalp and facial features, and judge by them the possesion or non-possession of certain mental and moral characteristics. Each of these faculties is supposed to be located in a certain specified area of the brain. The entire number of these characteristics or faculties is given as forty-three, each with its own particular location. The high point of belief in this alleged science was reached in 1830, there being at that time thirty phrenological societies. At the present time the modern exponents of character analysis make use of phrenology, physiognomy, palmistry, and hand-writing.

The progress of the scientific study of the brain has rendered this entire school obsolete. Practical anatomy, physiology and applied psychology have proved beyond question that the exterior of the skull is by no means an index to mental processes, this article has been an earnest student of character analysis, characteristics, faculties, abilities or aptitudes. The writer of phrenology and physiognomy for many years, but is forced by the evidence to believe that the wide-sweeping claims of the so-called character analysts rests on assumptions entirely unwar-

ranted by the facts. Among certain groups of well-meaning but gullible people the plausible "demonstrations" of these so-called character analysts pass for scientific fact and unfortunately in some parts of the country employment managers and industrial executives have been taken in by the promise of the acquirement of omnipotence and infallibility in a few easy lessons for a fat fee paid to these "professors" of character analysis.

Character analysis is not scientific; it is misleading and without any foundation or scientific basis that justifies its use in any situation of importance. The following points will give the reasons for this stand against the use in industry of the so-called science of character analysis of the phrenological and physiognomical type.

1. Although cerebral localization for certain sensory and motor centers has been scientifically demonstrated, it has also been scientifically demonstrated that there is no similar cerebral localization for such general traits of character as self-esteem, acquisitiveness, secretiveness, constructiveness, combativeness, calculation, language, firmness, spirituality, number, time, tune, weight, color and the rest of the forty-three faculties claimed by the character analysts. This at once sweeps away the foundation upon which the entire body of claims of the character analysts rests. Their main stock in trade is the claim that certain protuberances or depressions in the skull and certain shapes and lines of the features of the face indicate the possession or non-possession of certain specified characteristics or abilities.

2. No scientific data have been presented to prove that there is any correspondence between size and functional capacity of any portion of the brain. No scientist has as yet established any correlation between definite areas of the brain and specific mental, moral or emotional qualities, but it is a scientifically established fact that there is no correlation between the volume, shape or weight of the brain and the general traits of character emphasized by the analysts.

3. The evidence presented leads us to believe that functional capacity depends on the complexity and type of structure, of chemical and molecular action, on the convolutions, fissures, and on the quality of the brain structure, rather than on mere mass, weight or shape.

4. It is a scientific fact that the shape and varying thickness of the bones of the head are no indication as to whether brain tissues of any kind or cerebro-spinal fluid will be found underneath. In other words, it is a scientifically established fact that the conformation of the brain does not necessarily follow the conformation of the outside of the skull.

5. The entire body of claims made by the character analysts is based upon limited and very casual observation of exceptional cases, the observational method being used almost entirely throughout. The method used throughout the development of this so-called science has been first to establish a hypothesis and then to search until some exceptional case is found that will fit this hypothesis. It is just as easy to find cases that do not fit as to find those that do.

6. Most of these claims for ability to analyze character are not based on objective evidence that can be scientifically measured, weighed, formulated and tested. In all fields of science research men submit their findings and their evidence to scientific tests by their colleagues and other scientists, before they give their findings to the world, or attempt to use them for financial gain.

7. On the basis of physical stigmata alone we are unable to decide the presence or absence of specific traits or abilities, nor are we able to decide whether any individual is a desperate or degenerate criminal, a pervert, a mediocre person or a genius, an idiot, an imbecile, a madman or a fool. Fine hair or delicate skin does not necessarily indicate delicacy of perception, judgment or sensitiveness. A "convex, concave, or plane" face is no criterion of the quality of the brain or of its functioning. Lombroso, the Italian criminologist, about fifty years ago formulated a system for the detection of criminals by physical stigmata, such as the shape of the forehead, the nostrils, the lips, chin, the width of certain portions of the head, etc., but before his death his entire theory was exploded by Gross, the German psychologist, and was abandoned by Lombroso himself.

8. Up to the present time no character analyst has presented any scientific data as proof for the wide-sweeping claims and assertions made by them.

9. On the basis of the above facts we feel justified in taking the stand that the claims of the so-called science of character analysis rest on assumptions entirely unwarranted by the facts. This being the case we can assume that its use in any situation of importance will be misleading and harmful.

One of the most fundamental phases of our present civilization and particularly of our industrial and commercial development is the application of science to all phases of our everyday life. The modern manufacturer and business man is daily becoming more and more of a scientist. He must, and is, developing the scientific attitude of mind. This is the attitude which the writer has taken toward character analysis and has resulted in the conclusions formulated above.

THE ART OF WRITING SCIENTIFIC REPORTS

By F. H. NORTON

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THE report is the medium by which the results of investigation and research are conveyed to those people who are, or can be, interested in the subject, and like all mediums, to be efficient, it should carry its message as quickly and as smoothly as possible. It should not only transmit the actual data obtained, the cold facts and figures, but it should also carry to the reader a feeling of confidence in the work accomplished, and should so coordinate the results with similar work, that their true significance can be realized. A well-written report forms a reasonable and coherent addition to the world's knowledge. As the purpose of the report is to transmit as smoothly and easily as possible, certain facts and ideas, to the average person likely to read it, it must, then, be written in a full and simple enough manner to be comprehended by the least tutored, and still not be boring to the most learned, of the group who may be considered as interested readers. This demands clearness of expression, a concise though complete treatment, and an interesting style of writing.

Perhaps the most important quality a report can have is interest, for if it is not interesting it will not be read and if it is not read, it has failed in its purpose. Of course, some discoveries are of such great importance that, even though imparted in the most unpalatable form, they are widely and eagerly read, but these are only occasional instances, for the average piece of research is not of enough value for many to take the trouble to read carefully a muddled and dry report of the work. On the other hand, many will read a clear and interesting report even on subjects to which they have before given little thought. It is easy to tell an interesting report from an uninteresting one, but it is more difficult to determine what features distinguish a good report from a poor one. The most important feature in the creation of interest is probably the style of writing. Style is a rather broad and indefinite term, and various readers will not agree on what constitutes a good style, but writing that leaves the reader's mind in such a condition that

it can uninterruptedly and contentedly follow the meaning of the report, without being conscious of the words, is what I should consider a good style. Like every other piece of writing the report should have a definite object. There should be no digression from it, and there should be no doubt in the reader's mind what that object is. Awkward and incoherent sentences, abrupt beginnings and endings of ideas, and incomplete expression all tend to interrupt the smooth flow of meaning from the paper to the mind. There are, however, certain cases, when, for the sake of emphasis, it is desirable to bring out a statement strongly, by an abrupt breaking of the sequence of ideas, but this method, to be of value should not be frequently used. Besides the rather obvious requisites for good style, there is that rather indefinite quality that expresses the individuality of the writer. Some writers have the happy faculty of making anything they touch upon interesting, and, although it is impossible to explain just why this should be, I believe that the author must be really interested in his subject before he can interest his readers.

To have a wide influence, a report must inspire confidence. When a statement is made, it must be based on something tangible, so that there will be no feeling of doubt or skepticism as to its derivation. I do not mean that no statement should be made unless it is an indisputable fact, for that would greatly, perhaps entirely, limit them, but enough information should be given on the methods and apparatus used in experimentation, to allow the reader to accurately judge of their validity. For example, no one would have any confidence in a curve plotted from experimental data if the actual points observed were not placed on the curve, or at least a discussion of their accuracy included. Before any serious experimental work is done, the precision of the observations should be determined, so that it can be definitely known just what confidence can be placed on the results. Perhaps the surest way of winning the confidence of the reader is to record the data from two runs taken under identical conditions, the check run serving to indicate what may be expected in the way of precision in the remaining data. When, as is often the case, certain conditions not under the control of the experimenter, as for example the weather, give a considerable degree of uncertainty to his results, it should be completely explained, for the least hint of a lack of frankness will defeat the purpose of that report and will leave any other report by the same writer open to suspicion.

It is, of course, unnecessary to emphasize the importance of absolute integrity in any scientific writing, and yet it is so easy for even the best intentioned experimenter to be unduly influenced by some preconceived idea, that it may not be out of place to take up this point. It is very easy in many reports, without deliberately altering the data obtained, to considerably change the results by omitting facts that do not substantiate the theory that is trying to be proved. There are cases when undoubtedly this is intentionally done, but on the whole the writer is not conscious of any dishonesty, but simply has evolved a certain theory, and can not conceive of any results being correct that do not fit in with that theory. It is the most difficult thing in the world to approach a subject with an open mind and draw conclusions with entire impartiality, in fact the human mind is not constituted that way, and only with practise and care can we approach that ideal condition. We are always trying to twist the facts, wherever they have the least flexibility, to fit together into a reasonable whole, and it takes the greatest care not to twist them beyond the permissible limits. It is always better to omit a whole set of data, part of which is in disagreement with the rest, than to assume one portion as correct, and find in further experiments, that the wrong portion had been published, an embarrassment that I am afraid a good many investigators have experienced.

In order that the reader may understand the report as quickly and with as little effort as possible, it should be written clearly. Clearness depends on several factors, the most important of which is to write exactly what is meant. It is very difficult for a person who has studied a certain subject thoroughly, to put himself in the reader's place, and write with enough completeness to cover all uncertain points. Facts which seem to him self evident, are unknown to the reader, so that it requires the greatest care to cover all uncertainties that may arise in his mind. It is often the case that a person can write more clearly on a subject which he is still struggling with, than after he has completely mastered it. On the other hand, it is equally injurious to clearness to write too much. Long introductions, lengthy descriptions and the carrying of deductions beyond the limit set by the completeness and accuracy of the data, all tend to obscure the meaning. One of the most common faults in reports is profuseness, some writers having developed the art of expressing a one sentence idea into a whole paragraph, to a high degree. Such spreading tires the reader so that he often does

not take the trouble to search a whole page to find the few sentences of value. Writing reports with the idea of covering as many pages as possible is an excellent way of limiting its readers to those whose time is of little value.

As in any kind of writing, clearness is dependent on the three essentials, unity, coherence and emphasis. A report should not cover too much territory or no one will take the time to search for the particular part they want, and any digression takes the mind away from the main thought. The writer should not rush into his subject at full speed neither should he take an unduly long time to get started, or the reader's interest will be lost, but he should lead up to his subject naturally and directly in a few sentences or a paragraph, stating the reasons for undertaking the report. It has been the practise with some writers to summarize briefly their report near the beginning. This enables one to tell at a glance just what the report is about, and except for very brief papers, should always be done. The material in the body of the report should be arranged in a logical manner, description of apparatus, methods of testing, results and conclusions. The end of a report remains longest in the reader's mind, so that there should be placed the statements which it is desired to give the most emphasis. It is good practise in long reports to place subtitles before each paragraph or group of paragraphs so that any particular portion can be found at a glance. After a report has been written, it often happens that the author has some further additions to make; and instead of rewriting the report, the additional material is usually added in the form of a supplement or appendix. This procedure somewhat destroys the literary quality of the report, but is sometimes necessary. It is, however, a great help to clearness to place in an appendix any mathematical proofs and computations that are not absolutely necessary for the understanding of the report.

Photographs and other illustrations are of the greatest value; first to make the report interesting, and second to make it clear and concise. A report well illustrated, especially with photographs will be much more widely read than one without illustrations. A picture creates interest, because it stimulates the imagination and because it shows under just what conditions the experimental work was conducted, giving a more personal note to the whole report. Further than this, a good illustration is often the quickest way to convey an idea, and every one likes to absorb his knowledge with the least effort.

It often happens that a good illustration will do the work of a whole page of description and in about one tenth of the reader's time. For the same reason results should be shown wherever possible in graphical form, a method that is almost universally used. When the results can be plotted as precisely as the data permit, there is no need of giving the data in tabular form. Each illustration should have a title and a short explanation, so that the reader can tell at once what he is looking at without the necessity of searching through the text, and it is also advisable to place the illustrations as closely as possible to the portion of the text to which they refer.

There are many writers, some good and some poor, who convey an air of self-importance in their works which does much to detract from their popularity. It is right and natural that a man should be proud of a good piece of work that he has accomplished, but to constantly remind the reader of it, is certainly poor taste. A good report may be safely allowed to rest on its own merits, and will receive its recognition much quicker if accompanied by a degree of modesty. Again some writers make themselves unpopular by not giving credit in the report to the men who have been working under him during its preparation. No one ever gained anything in the long run by withholding proper credit, and I am sure they have never lost by showing the value of their assistants' services. Another bad habit some writers have is to depreciate the previous work of others along their line, and claim more originality for their work than the facts will permit. Such procedure leads only to unpopularity, and the public is never fooled for long. It is well, then, to write in a modest and straightforward manner, and to give others their due amount of credit.

There is always the problem of bringing together the so-called practical and theoretical men. The mathematician rather scorns the engineer who is not versed in higher mathematics, and the engineer, in turn, often regards the mathematician's work as a waste of white paper. It is strange how distinctly separated are the two classes and how few men really sympathize with both. It can be more or less truly said that the engineer's definition of theoretical, is something he can not understand, and the mathematician's definition of practical is something he can not do. As the mathematician is chiefly known through his writings, it is important that he present his ideas in a form that will do the greatest amount of good; that is, his reports should be read not only by his fellow mathe-

maticians, but also by the men who can make use of them in engineering and industrial development.

Even though a man has the training and the ability to handle higher mathematics, unless he has the time to frequently use it, it will soon become difficult for him to follow carefully the work of others. Also the engineer is too busy to spend much time on theory, even if he were able to handle it easily. There are, of course, a few men who are practical engineers and at the same time great mathematicians, but such men are few, as the average engineer feels that he can better obtain a mathematician to do his work for him than to spend the time himself.

For these reasons, the average scientific reports should not, as is too often the case, be so filled with complex mathematical discussions that real results and conclusions are so completely obscured that the engineer can not take the time to find them. In order to bring the physical meaning out clearly, plots should be frequently used. For example a complex equation representing harmonic motion would mean very little to most people, but a curve of the motion against time would show at a glance just what was meant.

There are a great many reports whose influence would be tremendously increased by the reduction of the number of integral signs and an increase in the number of illustrations. Most people will naturally skip quickly over any mathematics that occurs in a report in the same way that they would dodge a patch of mud in the street, and if the mud becomes too thick they will take some other way, and yet these are the people who could make the greatest use of the material contained in the report. On the other hand every one will look at a picture, especially a photograph, even though they are only remotely interested in the subject, and often their curosity will be aroused enough so that they will completely read the report. It is much easier to write a description than to make a drawing or take a photograph, but when it is considered that each person reading the report will be saved several minutes by doing the latter, there is no question of its value. In the same way it is easier to write an abstract equation than it is to give a clear physical conception of the relation, but the latter will save most readers much time and trouble.

There are of course reports which consist primarily of pure mathematics, and are of use chiefly to the mathematician, so that the writer can assume that all of his readers will have such an understanding of allied work, that it will be unnecessary to

go into detailed discussion of his results. And there are works of such advanced and original thought that it is impossible to describe them in terms that would be understood by any except the most illustrious scientists. Such works as these are unfortunately in a vast minority, and there are very few scientific reports that have no material of direct value to the engineer and the industrial chemist or physicist.

It may be well to say a few words about the mechanical side of report writing, and in doing so it will be necessary to digress a bit to the methods of experimentation and collection of data. All data should be collected logically and neatly, and everything should be labelled, as what may be clear and obvious at one time may be quite obscure after a lapse of a few months. Again it is well to work up the data as far as possible as the work goes on, not only to check up on the validity of the observations, and to determine the completeness of the data required, but also to get the results in such shape that they can later be readily combined into a report, and no pains should be spared to constantly check up the results obtained in order to detect errors that might affect a long series of experiments. A complete photographic record should be made as the work progresses, or it may be necessary later to go to considerable extra work to obtain an illustration.

After all the necessary data have been collected, it is generally best to construct an outline so that the methods used, the results and the conclusions may be placed in logical order and, after this, all plots and other illustrations should be prepared and numbered in their proper sequence. The first draft of the report can then be written or dictated, and a dictaphone is a very convenient instrument for this purpose. Very few can write a report just as they wish it the first time, and like all other kinds of careful composition it requires a considerable amount of revision. It is of great value to have the aid and criticism of others in this stage, as the author loses his sense of perspective after working for a long time on one report.

In conclusion, the purpose of the report should be to carry some fact or theory so interestingly, so briefly, and so clearly that the busy world will stop to read it, and having read it will pause to think, for the ability to make men think in a new way should be the aim of every writer.

THE ESSENTIAL CHARACTERISTICS OF UNITED STATES CLIMATES[1]

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Climatic Provinces of the United States.—For purposes of general description, it is convenient to subdivide the United States into certain climatic districts or provinces. The largest, or *Eastern*, extends from the eastern margin of the Great Plains, which roughly coincides with the 20 inch annual rainfall line and also with the 100th meridian, to the Atlantic Ocean, and southward nearly to the Gulf of Mexico. The strip bordering on the Gulf may be set apart as a subordinate district, the *Gulf* province. The *Plains* province includes the Great Plains proper, and extends westward to the Rocky Mountains. Between the Rocky Mountains and the Sierra Nevada-Cascade ranges comes the *Plateau* province. The Pacific Slope constitutes a natural climatic region which may be called the *Pacific* province.[2]

The differences between north and south, resulting from differences in latitude, suggest a further subdivision of the Plains, Plateau, and Pacific provinces into northern and southern sections. Similarly, the Gulf province occupies the more southern latitudes of the Eastern province.

The Eastern Climatic Province.—The Eastern Province, enormous as is its extent, is nevertheless characterized by great uniformity in its climatic conditions and in its weather types. It has a continental climate, but with abundant, or at any rate sufficient rainfall. Over most of it the seasons are strongly contrasted. The summers are very warm and the winters cold. But the hot summers, with sufficient rainfall, usually insure abundant harvests, and the cold winters, while severe in northern sections, are on the whole stimulating and tonic. The influence of the Atlantic Ocean is minimized by the fact that the prevailing winds are off-shore throughout the year, being north-

[1] Reference may be made to the following papers by the same author: "Two Climatic Cross-Sections of the United States," *Mo. Wea. Rev.*, Vol. 40, 1912, pp. 1909–1917; "Lorin Blodget's 'Climatology of the United States.' An Appreciation," *ibid.*, Vol. 42, 1914, pp. 23–27.

[2] See R. DeC. Ward, "Climatic Subdivisions of the United States," *Bull. Amer. Geogr. Soc.*, Vol. 47, 1915, pp. 672–680.

west in winter over much of the coast, and southwest in summer. Thus it follows that there can be but little of the tempering effect usually associated with conservative ocean waters, and the coastal belt, except when the wind blows onshore under general cyclonic or anticyclonic controls, or when, in summer, local sea breezes occur, does not differ very much from the interior. One aspect of this situation is clearly illustrated on the chart of equal annual ranges of temperature. The large ranges of the interior are carried eastward to the coast, and even on to the ocean for some distance offshore. The continentality of the Atlantic coast climate, with its slight marine modifications, was well described by Blodget when he wrote that on the immediate coast "a local oceanic climate exists, but it is always blended with the continental features which belong to this part of the continent generally."[3]

There are only relatively slight and unimportant differences of topography. The whole area is freely open, to Canada on the north; to the Atlantic Ocean on the east; to the Gulf of Mexico on the south. With the warm Gulf on the south and the cold Canadian plains on the north, the winter temperature-gradients between north and south are unusually steep. In January, the isotherms over the eastern United States are very closely crowded together. The temperature then decreases northward at the rate of 2.7° Fahr. in each degree of latitude, both on the Atlantic coast and in the Mississippi Valley. This is an extraordinarily rapid temperature-gradient, and may be contrasted with the very much weaker gradient along the western coast of Europe in winter. As seen on the chart of mean annual temperatures, one may go north in western Europe a distance of a thousand miles without finding a change of temperature as great as that met with in half as long a journey along the eastern coast of the United States. In summer, North America is well and relatively very uniformly warmed. There is then much less difference of temperature between south and north. The temperature-gradient is greatly weakened. It becomes 1.1° along the eastern coast, and 0.7° in the Mississippi Valley. The temperature conditions may be very briefly generalized as follows:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	40°	5°–10°	65°	100°–105°	—40° to —50°
S	65°–70°	50°–55°+	80°+	105°	zero–10°

The average dates of first and last frost, broadly generalized, are as follows:

[3] Lorin Blodget, "Climatology of the United States," 1857.

District	Last Spring	First Autumn	Av. Length of Growing Season
N	After June 1 (extreme N.)	Sept. (extreme N.)	3–4 months
S	Before March 1	November	7 months and over

Besides having a great uniformity of temperature conditions, considering its extent, the eastern climatic district of the United States also has, as a whole, a plentiful rainfall, well distributed throughout the year. Disregarding local areas on the mountains, the annual rainfall is greatest (50 + inches) towards the Gulf, and on the South Atlantic coast, most of the supply of water vapor for this precipitation coming from the Gulf and Atlantic Ocean, and decreases from about 40–45 inches over much of the north and central Atlantic coast and Ohio valley to 30–40 inches over the prairies, and 20 inches at about the 100th meridian. Although the rainfall is comparatively small at the western margin of the district, it is very well apportioned through the year. The maximum over the great farming states of the Mississippi valley region comes when it is most needed, *i.e.*, in the growing season of late spring and early summer. Of this region it has been well said:

> Although droughts sometimes affect considerable districts, and floods occasionally devastate the larger valleys, yet the world hardly contains so large an area as this so well adapted to civilized occupation.[4]

Nowhere in this district is there permanent necessity of irrigation, as there is in many places farther west. The rainfall comes chiefly from the ordinary cyclonic storms of the prevailing westerly winds. The spring and early summer rainfall of the Mississippi valley and adjacent regions is largely a local thundershower rain, and naturally occurs with the greatest frequency during the warmer months. In the colder season, with high pressures and with winds prevailingly blowing out from the continent, there is less opportunity for precipitation. In late summer the rainfall along the Gulf and Atlantic coasts is generally at a maximum, for the inflowing winds are then very warm and moist, and there are many thunderstorms. Along these coasts occasional West Indian hurricanes, in August, September, or October, give heavy rains and not infrequently damage buildings and crops. In Florida, the heavy August and September rains are almost tropical in character. In Tennessee and adjacent parts of Mississippi, North Carolina, Georgia, and Alabama there is a late winter or early spring maximum of precipitation.

[4] W. M. Davis, "Elementary Meteorology," page 301.

Rain falls most often, and hence the number of rainy days and the rain probability are greatest, in the Great Lakes region. This same district is also more cloudy than any other portion of the country except the northwest coast. The explanation of these conditions is found in the frequency of cyclonic storms, accompanied by general rains and by extended cloud sheets, over the Great Lakes and along the St. Lawrence Valley. Snow falls throughout a long season and in considerable amounts over these same northern and northeastern sections. Towards the south, the snow season becomes shorter and shorter; the snow lies on the ground less and less time. It finally becomes an almost, and then an entirely negligible factor.

Rapid and marked weather changes are characteristic of the eastern United States. These "paroxysms of change" (Blodget), which occur during the passage of numerous well-developed cyclonic storms, are unique for their suddenness, frequency and amount, especially in winter. They result from the bringing together, around the passing low-pressure centers, of winds of different directions and of very different temperature and moisture conditions, depending upon the characteristics of the regions from which these winds come. The winter dry northwest winds are often piercingly cold, coming as they do directly from the cold continental interior, and may cause a fall of temperature of 30° to 50° Fahr. in twenty-four hours, reducing the temperature to zero or lower ("cold waves"). They blow on the rear of cyclonic storms, and follow warmer and damper southerly or easterly winds which bring rain or snow. Several short periods of extreme cold are to be looked for every winter. During the warmer months, similar northwest winds bring the summer cool spells. The warmest weather, in winter as in summer, is brought by southerly and southwesterly winds which, coming from lower and warmer latitudes, blow north into a passing storm-center. In winter these southerly spells, while "unseasonably" warm, serve to break the monotony of the cold. In summer, with its high temperatures and high relative humidity, this same "sirocco" weather type is uncomfortably muggy and depressing, and often brings sunstrokes. The summers always bring spells of extreme heat of this type. In winter, the northeast cyclonic winds on the northern Atlantic coast are damp and unpleasantly chilly, blowing onshore from the cold ocean waters. In summer, their low temperatures bring welcome relief from the heat. In such a region, where sudden and irregular weather changes are so characteristic, climatic averages can give little

idea of the actual conditions which are experienced from day to day. Seasons often differ markedly in character from year to year. Weather changes are erratic and unexpected. It has become a popular saying that almost any kind of weather may be expected at any time of the year.

Thunderstorms, many of them of wide extent and of great violence, are characteristic summer phenomena over the eastern and southern United States. The far more severe tornadoes, fortunately of much less frequent occurrence, develop most often over the great lowlands of the central and upper Mississippi and of the lower Missouri Valleys. Tornadoes, as well as the more violent thunderstorms, have a habit of springing up along the dividing ("wind-shift") line between the warm southerly ("sirocco") type of weather in front of a passing summer cyclonic storm and the cool northwesterly (summer cool wave) type on its rear.

The Gulf Province.—Over the southern tier of States bordering on the Gulf of Mexico the temperatures are higher; the winters are much milder; the summers are longer and hotter; the rainfall is heavier, and has a late summer or early autumn maximum. With increasing distance from the most frequented cyclonic paths, which follow along the northern border of the United States, the cyclonic control is weaker; the irregular wind, temperature and weather changes are fewer, less sudden, and less emphatic; the diurnal phenomena are more marked, even in winter; the weather is more stable; conditions are more settled. In winter, cyclones which give heavy snows and marked wind changes followed by cold waves over northern sections, often bring but little cloud and rain, without marked temperature variations, over the Gulf States. The southern States are, nevertheless, subject to occasional invasions of considerable cold in winter, during the prevalence of north and northwest winds on the rear of well-developed cyclonic storms. These winter cold waves sweep east and southeast as far as the southern Atlantic and Gulf coasts, but their intensity diminishes rapidly as they advance into more southern latitudes. The occurrence in districts of high mean annual temperature of frosts of sufficient severity to injure the more sensitive crops, is a characteristic of southeastern North America, and is one of the marked, and economically one of the most unfortunate, features of the climate of the Gulf Province, which is otherwise in many ways singularly favored. Snow becomes a rarity. Over the sections immediately adjacent to the Gulf, it is practically negligible. On the warm, damp lowlands there is the

wealth of southern cotton, and sugar cane, and semi-tropical fruits, and from the truck gardens of the southern Atlantic coast immense quantities of early vegetables are shipped north, by rail and by water, to the markets of the great northern cities. The severe winters in the north effectually put a stop to most outdoor occupations during the colder months, although giving rise to others, such, *e.g.*, as ice-cutting and lumbering. In the Gulf Province, on the other hand, and over the closely adjoining sections of the Eastern Province, most agricultural and other outdoor work can be continued throughout the year.

The Plains Province.—The essential difference between the climate of the Great Plains and that of the Eastern province is not so much one of general temperature conditions as of rainfall. The Plains, like the rest of the great region lying to the eastward, have a continental climate. They lie at a distance from large bodies of water, and have massive mountain barriers on the west, between them and the Pacific Ocean.

The following table summarizes the temperatures:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	40°	0°–10°	65°–70°	105°–110°	—50° to —60°
S	65°	40°–50°	80°–85°	110°	zero

As compared with the eastern States, the Plains have larger diurnal ranges of temperature; more abundant sunshine; drier air; greater evaporation; smaller rain probability; less rain; more wind. The prevailing winds have a monsoonal character: they are northerly and northwesterly in winter and southerly and southeasterly in summer. There is a well-marked diurnal variation in velocity on days whose weather is not under strong cyclonic control.

Rainfall is the fundamental climatic factor. From the more abundant precipitation towards the Atlantic and Gulf, the mean annual rainfall decreases westward until, at the eastern margin of the Plains, it averages about 20 inches, and towards the western margin decreases still further to below 15 inches. No sudden change, either in topography or in climate, takes place along the 100th meridian, but where the mean annual rainfall averages less than 20 inches, the amount is too small, under ordinary circumstances, for permanently successful agriculture, on a large scale, without irrigation. Another disadvantage of a small rainfall is its variability from year to year. Remarkable results have been attained by "dry farming" methods over parts of the Plains, in the case of certain crops which require little water, and in seasons with favorable rain-

fall. Dry farming is, however, a precarious venture, and can not be counted on to give results comparable with those obtained in a well-watered or well-irrigated country. The natural limitations of the country are clearly recognized. Its best use is not to be found in the old-time boundless cattle ranges, nor in vast farms which depend solely upon the natural rainfall, but rather in smaller individual farms and cattle ranches, where irrigation from streams or from ground-water is possible. The relatively high and steady velocities of the winds over the Plains have proved a reliable source of power in driving the windmills which are widely used for pumping water for irrigation. This relation of the 20 inch rainfall line to agriculture has locally long been recognized. "East of it lies success; west of it, failure. Look out for the 'dead-line.'" The critical boundary thus termed the "dead-line" has played an important part in the settlement and development of the Great Plains.

The distribution of the rainfall in normal years is singularly favorable over most of the Plains province. The maximum usually comes in late spring or early summer, when moisture is most needed by the growing crops. To the southward (New Mexico), the maximum is retarded until mid- or late summer. These warm-season rains are spasmodic, and fall chiefly in the form of brief and local thundershowers. Winter is the dry season. In the north, the winter precipitation is mostly in the form of snow, but the amounts are considerably less than those of the same latitudes farther east. Over the southern Plains, where the winters are warmer, the winter snows average under 10 inches in depth, and are even under 5 inches in western Texas and southernmost New Mexico.

Cyclonic control is less marked than in the east, partly because fewer cyclonic storms pass over or near the Plains, and partly because the storms are generally of a milder type. Irregular weather changes are most frequent over the northern Plains States, which are nearer the main storm track. In the south, the sequence of weather changes is much more uniform. Diurnal rather than cyclonic controls are dominant most of the year. The more severe winter cyclones bring sudden temperature changes, severe gales, driving snow and extreme cold ("blizzards"). Cold waves, sweeping southward and eastward from western Canada, occasionally reach as far south as Texas, where they cause sudden and marked falls in temperature, with chilling northerly winds ("northers"). Much of the winter weather, however, is dry, clear, settled and bracing. Locally, along the eastern base of the Rocky Mountains, the

winter cold is often tempered by warm *chinook* winds. Long spells of hot, dry, typical, diurnal weather, with southerly winds, are characteristic of much of the summer. When continued for many days, or sometimes even for weeks, unbroken by general rains or by widespread thundershowers, such spells are associated with extended droughts and result in injury to crops, especially when accompanied by certain hot and dry winds which are characteristic of the Great Plains ("hot winds"). While thunderstorms are of frequent occurrence during the warmer months, tornadoes are relatively rare.

On the west, the Plains province gradually merges into the eastern foothills and slopes of the Rocky Mountains. Here the greater elevations and the topographic irregularities give rise to special climatic features which are associated with mountain and plateau climates. Colorado has become famous for its health resorts. With a small annual rainfall; light winter precipitation; few storms; little cloudiness; dry, stimulating air, and comparative immunity from many of the sudden and severe weather changes characteristic of the east, there are evident advantages for invalids in this region.

The Plateau Province.—The *Plateau* province is a great interior region of very diversified topography. It has a wide range of mountain, high plateau and arid lowland climates, superposed upon and causing local modifications of the general dry continental climate of the province as a whole. "Climatological topography" (Blodget) is here highly significant. The diversity of topography results in a very "patchy" distribution of climates and of vegetation, as local variations of temperature, frost, rainfall, etc., may determine. The winds, also, are largely topographically controlled, both in the case of the local mountain and valley breezes and of the more general cyclonic wind directions.

The outstanding characteristic is the small rainfall, which, however, shows marked increase with altitude. The higher mountains and plateaus have distinctly more precipitation than the neighboring lowlands. With the exception of local areas in the mountains, the mean annual rainfall is everywhere less than 20 inches; it is mostly below 10 inches, and over no insignificant portion of the southwest it is even below 5 inches. This is the region of what, not many decades ago, was known as the "Great American Desert"; of Great Salt Lake; of the interior drainage basis of Nevada, the "artificial State." The real "American desert" is in southeastern California, southwestern Arizona and western Nevada. Death Valley is here, with

its famous borax and its intense summer heat. The Salton Sea is here—an anomaly in a true desert. The Black Rock desert; the "sinks," and the soda deposits of western Nevada are here. With the high mountain barrier on the west, the whole plateau district is in the rainshadow. Arid or semi-arid conditions are to be expected, except where the higher mountains or plateaus give rise to more plentiful precipitation, especially in the north, where general storms occur more frequently, and where the barrier is less effective. Even in the south, where the rainfall is less, the higher elevations are fairly well watered. The name of the Aquarius Plateau is a suggestive one. The Rocky Mountains are so far from the Pacific that their rainfall is not as a whole heavy. They are, furthermore, to leeward of the considerable ranges of the Sierra Nevada-Cascades.

Irrigation is made necessary by reason of the deficient rainfall, although dry-farming is carried on in certain sections, as, *e.g.*, in eastern Washington, with considerable success. Wherever the streams, supplied by the melting snows and the heavier rainfall of the higher mountains, afford sufficient water, there green oases of varied crops, dotted with fruit and shade trees, break the monotony of the "desert." Most of the winter precipitation is in the form of snow, which is decidedly heavier in the north than in the south, and over the higher elevations than over the lower lands. In the far southwest, snow is rarely seen except on the mountains. The rainfall distribution through the year varies greatly in different portions of the district. In the north, there is generally a late winter or early spring maximum. In the south, the primary maximum usually comes in late summer, with a secondary maximum in winter. The winter rains and snows are cyclonic. Frequent, often daily, thunderstorm rains are characteristic of the warmer months, especially over the mountains. The rain probability is below 20 per cent., and the minimum number of rainy days in the United States is found in the far southwest (under 30).

Temperatures are so largely controlled by the topography that even broad generalization is almost impossible. The essential facts may roughly be given as follows:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	50°	25°–30°	65°–70°	100°–105°	—10° to —30°
S	60°–70°	40°–50°+	80°–90°+	110°–120°+	zero to 20°

Minimum temperatures and frost occurrence are mostly a matter of local topographic control and of local air drainage.

The dates of first and last frost are very variable. The summers of the southern lowlands are long and intensely hot, but the low humidity is an important factor in making the high temperatures endurable. The southern winters are comparatively mild, dry and bracing. In the north, the heat of the summer is much less severe, and the winters are colder. The districts west of the Rocky Mountains are, however, to a great extent protected against severe cold waves of the eastern type. Dry, stimulating air; an abundance of sunshine; large diurnal ranges of temperature—these are dominant characteristics of the Plateau climates, taken in the large. Diurnal ranges of 40° or more are by no means uncommon. Cool nights follow hot days in summer, especially on the mountains and plateaus. Periodic diurnal, rather than irregular cyclonic, weather types are dominant.

The Plateau province is beyond the reach of most of the cyclonic storms which so largely control the weather and climate of the rest of the country. At intervals, winter storms, coming from the Pacific, cross the northern portion of the district on their eastward course along the northern track, and other, but not greatly frequented, storm tracks cross the central and southern parts. Hence, as a whole, there is a decided lack of sudden, irregular and severe weather changes. The maximum cyclonic control, here as elsewhere, is in the colder months, but few of the winter storms bring heavy precipitation. Even in winter, long spells of fine, bright weather, with light winds, moderately warm days and cold nights are common. Summer weather is characteristically fine and settled, broken by afternoon or evening thundershowers, and occasionally by the cloud sheet and general rains of a passing summer cyclonic storm.

The Pacific Province.—Over the narrow Pacific coastal belt climatic conditions are quite unlike those elsewhere in the country, and in many respects resemble those of northwestern and western Europe, including the Mediterranean area. Blodget gave an excellent brief yet comprehensive climatic comparison when he wrote that "the Pacific coast climates are Norwegian, English and Spanish or Portuguese, with the intermediate France blotted out."[5] The similarity of climates in southern California and in the countries bordering upon the Mediterranean explains the similarity of many of the agricultural products and fruits, and of the general methods of cultivation, in these two regions. Exposed to the influence of the warm

[5] Lorin Blodget, *loc. cit.*

Pacific, with the prevailing westerly winds coming directly from the conservative ocean, and protected on the east by high mountains, the Slope as a whole has a modified marine or windward coast climate. A typical west coast subtropical climate is found in California. The wide range of latitude between north and south, together with the varying topographic controls and the differences of exposure to the ocean influences, explain the great variety of climates which are found in this province. These range from those of the rainy and densely forested slopes of Washington to those of semi-arid southern California; from those of the lowlands to those of the snow-covered mountain tops; from the cool summers of the coast to the hot summers of the Great Valley. The climate is, in general, mild and equable, with slight diurnal and seasonal ranges. The relatively small seasonal change is common both to the cool and humid climate of the far northwest and to the warm and dry climate of the southern interior.

The following table summarizes, in a very general way, the essential temperature characteristics of the Pacific province.

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	50°–55°	35°–40°	60°–65°+	95°–105°	10°–0°
S	65°±	50°–55°	65°–75°+	110°–115°	20°±–10°

The relatively high winter temperatures insure the Pacific coast harbors against freezing, whereas on the northern Atlantic coast ice not infrequently causes difficulty to navigation in severe winters. Further, the mountain barrier of the great Sierra Nevada and Cascade ranges to a large extent keeps out the extremes of winter cold which are found over the interior districts to the east. Under the influence of the warm ocean current eddy which circulates from right to left in the Bay of Alaska, and of the cool return current which flows along California and Mexico on its way equatorward, the isotherms along the Pacific coast are spread far apart. Hence there are but slight differences of temperature between north and south along the coast, and the rates of temperature-decrease per latitude degree from San Diego to Sitka are but 0.95° in January, 0.65° in July, and 0.8° for the year. These temperature-gradients may be compared with the much steeper gradients of the Eastern province, previously referred to. The chart of equal annual ranges of temperature shows clearly how small is the seasonal change of temperature along this coastal strip (not over 25°), while across the mountains, in the interior, the ranges reach 40°, 50° and even 60°. No such severe winter

cold waves are experienced here as to the east of the Rocky Mountains, or even over the Plateau. The area over which frost does not occur annually includes southern California. In the region around San Diego, killing frost occurs in less than half of the winters. The attractions of outdoor life during the colder months in southern California have made this locality a favorite winter resort for those who wish to escape the rigors of more severe northern latitudes.

The interior valley of California, between the Coast Range and the Sierra Nevada, being well shut off from the ocean, is very hot, dry and sunny in summer, especially in the south, while the immediate sea-coast is cool, damp and often foggy. The crowded July isotherms show very clearly the difference between the temperatures of the interior and those of the coast. This is one of the most remarkable contrasts in the world over so restricted an area. The strong diurnal ranges of temperature over the interior valley give relatively cool nights and the dryness of the air relieves the great heat of the days. The high inland summer temperatures result in the prevalence of cool onshore daytime winds, which are unusually well developed at San Francisco. Sea-breezes are a characteristic feature of the whole coast.

The rainfall is heavy (over 100 inches) on the northwestern coast of Washington, and decreases rapidly to the south, to about 10 inches on the extreme southern coast of California, and less than 10 inches in the San Joaquin Valley. There is a marked seasonal periodicity. The maximum comes in winter. General cyclonic storms are then most frequent; they then travel farther south; the land is colder than the ocean; the prevailing winds have more of a southerly component. Some southern districts are actually without any rain in summer, and then become very dry and dusty. In the north, however, it rains more or less all through the summer months, although the winter maximum remains. The rainfall migrates from north to south as winter approaches, *i.e.*, the rains in the south are distinctly subtropical in character, and correspond to the winter rains of the Mediterranean districts of Europe. As Woeikof first pointed out, these rains extend farther north in western North America than happens anywhere else in the world.[6] The rains come when the "stormy westerly winds" are farthest south, and cease when the northward migration of the tropical high pressure belt displaces the storm-bearing westerlies polewards. Even in the so-called "rainy season"

[6] A. Woeikof, "Die Klimate der Erde," 1887, p. 24.

of winter, the rains are generally light; they are not steady and continuous, usually lasting but two or three days and separated by spells of fine, sunny weather. On the extreme northwest coast, rain falls on nearly half of the days in the year. There is a marked decrease in the number of rainy days, as well as in the mean annual rainfall, from north to south. From the point of view of an outdoor life, southern California is favored in having very few rainy days. Over the lowlands of the Pacific Slope, snowfall is of little importance. Even in the north it is very light, and on the coast it becomes practically a negligible factor south of the northern boundary of California. On the mountains, however, even in southern California, snow falls frequently, and on the western slopes of the high Sierras and of the Cascades it is very heavy. The water-supply from these melting mountain snowfields is of supreme importance in irrigating the fertile and productive valleys and lowlands, whose natural water supply, in the form of rainfall, is insufficient for agriculture and for fruit-raising.

The Pacific Slope is not subjected to violent weather changes. During the winter, a series of general cyclonic storms moves eastward across the northern portion of the province, and occasional storms come in farther south, or their paths carry them south to the more southern latitudes. Hence the northern districts have more rain, more cloud, and more frequent weather changes than the southern. The amount and distribution of the annual rainfall are controlled by the number, intensity and paths of the winter storms. When these extend farther southward, and are better developed, the rainfall is heavier and more widely distributed. In general, rain falls with the cyclonic winds in the southern quadrants, and fair weather prevails with northerly cyclonic winds. The changes in wind direction bring changes of temperature, but the general temperature gradient being weak, and the regions from which the different winds come not differing greatly in temperature, sudden and marked rises and falls of the thermometer do not occur. In general, southerly to westerly winds are warm in winter and cool in summer; northerly to easterly winds are cool in winter and warm in summer. The rains of summer, where they occur, are as a rule light and local in character, and fall mostly in the north and on the mountains. The cold-season precipitation comes in the form of general cyclonic rainy spells. Thunderstorms are infrequent, and usually light; rarer on the coast and more common inland and on the higher mountains. Special cyclonic winds, having certain marked

peculiarities, occur over some sections, under the combined control of the pressure distribution and of the topography. The "northers" of the great valley of California have a chinook or foehn character. They are dry and dusty and may be injurious to crops. The "Santa Ana" of southern California is also a hot, dry and dusty wind, somewhat similar to the norther. It blows from northerly or easterly points, and is trying to men and animals. Coming from the dry interior, it reaches the southern coast with the characteristics of a desert wind.

The Valley of California is a great agricultural and fruit-raising district, as is the Willamette Valley in Oregon. The summer dry season is a favorable climatic feature during harvest-time, and for drying fruits in the open air. The western slopes of the Sierra Nevada are well watered and forested, while the eastern (leeward) slopes are dry. On the Cascades and on the northern Coast Range there are also abundant forests. North of San Francisco, on the western slope of the Coast Range, are the famous redwood trees, and the "Oregon pine," from farther north, has been known the world over because of its usefulness for ships' masts and spars.

BIBLIOGRAPHIC NOTE.—For general statistical information concerning all parts of the United States reference may be made to the "Summaries of Climatological Data by Sections" (*Bulletin W*, U. S. Weather Bureau, 4to, Washington, D. C., 1912. 2 vols. Price 5 cents for each section; 10 cents for any three sections; $3 for entire set unbound. To be obtained from the Superintendent of Documents, Washington, D. C.) The period covered by the data varies. Reprints are issued from time to time for the various sections, containing all the data included in the first edition and also bringing the observations down to later dates. Several important additions to the tables have also been made in the reprints. (See also, R. DeC. Ward, "A Short Bibliography of United States Climatology," *Journ. Geogr.*, Vol. 17, Dec., 1918, pp. 137–144.)

THE PROGRESS OF SCIENCE

THE SCIENTIFIC MEETINGS AT CHICAGO

THE American Association for the Advancement of Science and the special scientific societies affiliated with it meet at Chicago during the week beginning December 27, this being the seventy-third meeting of the association, the eighteenth convocation week meeting of scientific societies, and the third of the greater convocation week meetings held at four year intervals in Washington, New York and Chicago. It is planned that at these meetings in our large centers of scientific population there shall be a full representation of scientific societies and special efforts to promote science and the appreciation of science by the largest possible public.

The promise for the Chicago meeting is auspicious. In the past four years science has successfully met the supreme emergency of war and in the ensuing reconstruction period it will be the principal factor in our complicated civilization. These facts are perhaps more nearly recognized than ever before, and the approaching meeting will do much both to advance science and to secure increased support of science by public recognition. It is also the case that every four year period signalizes a further development of scientific institutions and scientific activities in the central and western states, so that the center of scientific population bids fare to correspond with the general center of population, and this circumstance will be reflected by the approaching meeting.

Dr. L. O. Howard, chief of the Bureau of Entomology, United States Department of Agriculture, the president for the Chicago meeting, has been permanent secretary of the association for twenty-two years, during which time the membership has increased from 1,729 to over 12,000 and the meetings and other activities of the association have grown in proportion. As the Chicago meeting celebrates the completion of Dr. Howard's successful administration, so it marks the beginning of the secretaryship of Dr. Burton E. Livingston, professor of plant physiology at the Johns Hopkins University, during whose term of office it may be expected that the association will progress even more rapidly than the science of the country on which it depends and which it in turn promotes.

The address of the retiring president will be given at the opening general session on the evening of December 27 by Dr. Simon Flexner, director of the Rockefeller Institute for Medical Research. Sessions of general interest are planned for fourteen sections of the association, representing different fields of science, and the retiring vice-presidents for the sections will each give an address on some broader aspect of his own field. Some forty affiliated and associated societies will hold meetings for the reading of papers and for discussion.

Most of the sessions will be held at the University of Chicago which in a comparatively short period has taken its place among the three or four universities which are most active in the advancement of science. Only two previous meetings have been held in Chicago, the first in 1866 and the second in 1908. The

earlier of these meetings represented a new era in the work of the association, the meetings of which had been suspended during the war. There had been an informal meeting at Buffalo in 1864, attended by 79 persons, and a meeting the following year at Burlington was attended by 73. At the time of the meeting in 1868 the membership of the association was 428 and there were 259 in attendance. The sessions were held in the assembly hall of the Y. M. C. A. and the Baptist church, the meeting being held under the auspices of the citizens rather than of any educational or scientific body.

The meeting of 1908 was held at the University of Chicago with an attendance of 723 members, and it was estimated that, counting members of the affiliated societies, there were some 2,000 scientific men in attendance. Dr. William H. Welch, of the Johns Hopkins University, gave the presidential address; Professor Edward L. Nichols, of Cornell University, presided, and the president elected was Professor T. C. Chamberlin, of the University of Chicago. It was one of the most notable meetings of the association that has been held, and it may be expected that the meeting to be held at the end of December will make new advances in scientific organization, in scientific research and in the appreciation and support of science by the general public.

PROBLEMS OF A NATIONAL ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

An interchange of delegates between the American and British Associations has been planned, and a joint meeting of the two associations on the common ground of Canada could be arranged with advantage both to science and to international friendship. The British Association, founded in 1831, was a model for ours, and we still have much to learn from it. For example, it is doubtful whether the addresses of the president and vice-president of the American Association always maintain as high an average standard of style, proportion and general interest as those presented at Cardiff, parts of which have been printed in this journal.

There may also be faults that the British and American Assocation share and, in so far as this is the case, the vigorous criticism of the conduct of the British Association that has been printed in *Nature* and other English journals since the Cardiff meeting should be of interest here as well as there. Indeed it must be admitted that the failure of the association to keep in touch with the general public—which is the principal charge against the British Association—is even more obvious in the United States. There is, however, this difference that while the English press and the people still pay more attention to the scientific work of the association and treat with greater consideration men engaged in research, there is a tendency for the two countries to reach a common level. Formerly the London *Times* gave whole pages daily for a week to the British Association, while now the space is reduced to a column or two and the topics treated are likely to be education, economics and the like. It seems that the same decrease in interest, especially in the more serious aspects of scientific work, is shown at the place of meeting. Still, it is the case that the local committee at Cardiff spent about $7,500 in entertaining the association, which the Chicago committee would probably regard as beyond the resources of that rich city.

Some of the comments regarding

the British Association are as follows:

I think that our "British Association" is in an unhealthy condition owing to the attempt made by it—not deliberately, but by constitutional looseness of purpose—to combine the features of a friendly picnic and smoking debate with the work of a national conference dealing (under the disadvantage of public ignorance and journalistic inaccuracy) with great questions of national importance. A choice must be made between "picnic" and "conference." I should prefer the picnic. —E. RAY LANKESTER.

Unless the British Association becomes democratic and acts as a real bond of union between scientific men and the thinking public, rather than as a periodic platform for personages, it does not seem to fulfil any function worth continuing. The public application of science is a totally different thing from applied science. This scientific synthesis and the direction of the unique mental attitude, induced only by the actual discovery of new knowledge, to the conduct of public affairs are the real and peculiar functions of the association if it is to regain its national position. Curved space, isotopes, and the economics of life on the floor of the ocean are topics of great interest to hundreds of the public. The standards of truth which science has set up, and the elevation of its pursuit above sophistry, chicanery, and the monotonous motives of self-interest, inspire the imagination of hundreds of thousands. The British Association seems to be attacked by senile paralysis just as a belief in science and in the power of its methods is arising in the world phœnix-like from the ashes of its old self.—FREDERICK SODDY.

Your criticism of the British Association, that it fails to touch our national life, is most opportune; but whereas you imply merely that it is decadent, to me it seems to be practically defunct. An active worker on its behalf in the past, I have little hope of its resuscitation and doubt if it can ever again fulfil the desires of its early promoters, who undoubtedly held its primary function to be that of advancing public appreciation of scientific discovery. I have always deplored our failure to appeal to the public. Seemingly, the spirit of sacrifice is gone out of science; strange to say, the herd instinct is altogether wanting in our society, so uncontrolled is our individuality. The assumed author of "The Beggar's Opera," after remarking of his characters, "There's not an honourable man among them, nor an honest woman," proceeds to say, "but they are all human." So are the present exploiters of the British Association, though were it not human to be selfish some might even dub them inhuman on account of the narrowness of their outlook and their disregard of public needs.—HENRY E. ARMSTRONG.

These are the more extreme criticisms. Letters and articles in defense of the association have also appeared and the honorary secretaries, Professors J. L. Myers and H. H. Turner have prepared a statement answering criticisms and outlining plans for the future work of the association.

THE ORGANIZATION OF SCIENTIFIC RESEARCH UNDER THE BRITISH GOVERNMENT

OUR federal government has more scientific men in its bureaus and devotes larger sums to scientific work than any other nation. An immense amount of useful work is accomplished, but individual initiative is likely to be submerged by routine. It may, therefore, be worth while to note how the British Government has met the situation during and since the war period.

The last report of the Committee of the Privy Council for Scientific and Industrial Research contains an account by Sir William McCormick of its activities since its foundation in 1915. According to an abstract in the *Spectator* the program which has been elaborated by the advisory council during these five years classes its functions under four main heads. First comes the encouragement of individual workers at research. The special claims made by the needs of the war practically denuded the universities of research workers. Now that peace has returned other dangers have arisen. On the one hand, the universities are overcrowded with students, and the demands of teaching

are leading to an impending shortage of those research workers, without whom no science can advance. On the other hand, the revival of industry is tempting men away from "the corps of research workers" into the service of the great manufacturing corporations. During the past four academical years the Advisory Council has spent about £50,000 in maintenance grants to research workers, and it expects to spend nearly as much in the forthcoming year. "No conditions are attached to the grants made to workers whose sole aim is the extension of knowledge, either as to the line of their work or as to the use to be made of the results," though, of course, great care is taken that the recipients of state aid should be genuine workers at the solution of a knotty problem.

The second part of the program includes the organization of research associations for special industries. A large and wealthy firm has its own laboratories and its own staff of chemists or physicists. But in many industries the firms are too small to do this work for themselves, and in all industries cooperation saves waste and duplication of effort. A fund of a million sterling was authorized by Parliament to assist in the establishment of research associations, of which eighteen are already at work and five others have been approved. The firms connected with the existing associations have undertaken to raise an annual sum of nearly £40,000 for their purposes, and it is probable that this income will be largely exceeded as the benefits derived from research become practically apparent. The industries which already have research associations in existence are those of cotton, linen, wool, leather, bootmaking, laundering, sugar, cocoa and jam, motoring, glass, iron, nonferrous metals, rubber, photography, scientific instruments, Portland cement, refractory materials, and shale oil. It is much to be hoped that the rapid growth of these promising infants will soon convince industry as a whole of the necessity for scientific research as a basis for the profitable union of Capital and Labor.

The third item in the program of the Advisory Council is the conduct and co-ordination of national research; in other words, provision for dealing at the national expense "with certain fundamental problems which were of such wide application that no single industry, however intelligent or highly organized, could hope to grapple with them effectively." The first of these basic problems is that of fuel, to study which the Fuel Research Board was established in 1917. Closely allied is the conservation of coal and mineral resources. The problem of the preservation of food and that of building materials and construction are also being handled by special Boards. The Geological Survey and the National Physical Laboratory have been handed over to the Research Department. The Radio Research Board takes its place beside three new boards, dealing respectively with chemistry, physics and engineering, to coordinate the scientific work still required for the fighting services. The fourth item of the program is the granting of aid to scientific and professional societies for purposes of research.

ENGLISH MEDICAL LABORATORIES

Medical service in England is more elaborately organized under the control of the state than in the United States. There is a Ministry of Health which has appointed a medical consultive council and this council has presented a report which

is now under consideration. The *British Medical Journal* prints an abstract according to which it is pointed out that medical treatment must be both individual and communal, and that individual treatment may be either domiciliary or institutional. By communal treatment is to be understood pre-natal and maternity care, child welfare, the inspection and treatment of school children, dental treatment, clinics for early tuberculosis, and facilities for physical culture. The general conception is that domiciliary treatment in each district should be based on a "Primary Health Center." This institution would be conducted by the general practitioners of the district, and would be provided with an efficient nursing service. It would be linked with a "Secondary Health Center" in some town conveniently placed in relation to the means of communication. Opportunities would be provided for consultation, either at the primary center or at the homes of the patients, with physicians, surgeons, and specialists of the secondary center, which would itself be brought into corresponding relation with a medical school hospital.

A sketch is given of a scheme for laboratory services. The first and essential function of the laboratory at a primary center would be to give facilities to the general practitioner; it would be so equipped as to enable him personally to make any examinations he desired to undertake. The equipment would be supplied from the secondary center and adapted to meet any increase in knowledge, skill and interest displayed by the practitioners concerned. Some person must be placed in charge of such a laboratory; it is thought that his qualifications might vary with the size, geographical situation, and special needs of the center.

The laboratory of a secondary center should provide ample accommodation and equipment, and its senior staff should be highly qualified to do clinical laboratory work, both for the primary center and for the hospital of the secondary center; it would also do postgraduate teaching. The head of the laboratory would be a well qualified pathologist, and the staff would comprise specialists in morbid anatomy, bacteriology, and pathological chemistry. Some of the assistants would be preparing for the higher posts in the service; others in an intermediate class, would furnish recruits for the staff of the primary center.

The laboratory of the secondary center would be linked with the chief or university center, which would have a special laboratory for health services distinct from a professorial department, though in close contact with it. A separate health services laboratory would protect the academic staff from routine, leaving it free for teaching and fundamental research work. The staff of the health services laboratory would be recruited from that service and be dependent upon meritorious performance within it. At the same time it is recognized that no rigid barrier should be erected between the academic pathologist and those engaged in the health services. Though there would be two distinct careers, circumstances would often cause individuals to pass from one to the other.

The health services laboratory of a university center in addition to the routine work, would carry out the more difficult investigations referred to it from the subsidiary centers, but it might also undertake much of the routine work for the university hospital. The director of such a laboratory would rank with a university professor, but would usually be a distinguished

pathologist with tastes inclined to organization and administration rather than teaching.

With regard to research, it is suggested that the organization throughout the proposed health service would facilitate inquiry into the causes of disease. It is suggested that the facts showing the need for inquiry might often be brought together in the first place by the medical practitioners in a locality; the manner in which it should be further prosecuted would depend upon the subject, but research into fundamental problems would still continue to be conducted through the university and the Medical Research Council. A national organization of laboratories in touch with every branch of the health services would, it is believed, provide opportunity for systematic investigation and team work. The director of the health services laboratory at the university center would be in a position to start machinery for the intensve investigation of any urgent problem, and with the goodwill of the general practitioners the investigation would include cases never available in the wards of a hospital. In particular, the earliest stages of disease might be made the subject of organized research, which, it is hoped, might be subsidized and perhaps supervised by the Medical Research Council.

SCIENTIFIC ITEMS

We record with regret the death of Harmon Northrop Morse, for forty-four years associate and professor of chemistry at the Johns Hopkins University; of Samuel James Meltzer, head of the department of physiology and pharmacology of the Rockefeller Institute for Medical Research; of Arthur Searle, professor emeritus of astronomy at Harvard University; of Isadore Dyer, dean of the medical school of Tulane University; of Yves Delage, professor of zoology at the Sorbonne, Paris, and of Sven Leonhard Törnquist, professor of geology at Lund.

Nobel prizes have been awarded to Dr. Jules Bordet, professor of bacteriology at Brussels, and Dr. August Krogh, professor of physiology at Copenhagen.—Professor Stephen Moulton Babcock, of the University of Wisconsin, inventor of the Babcock test for determining the amount of butter fat in milk, reached his seventy-seventh birthday on October 22, and in honor of the event and of his work a university convocation was held. Professor Babcock is engaged in active work in his laboratory.

The International Congress of Mathematicians at the Strasbourg meeting accepted the invitation presented by Professor Leonard E. Dickson to hold the next congress in New York in 1924.—At the International Congress of Physiologists, held in Paris, it was resolved, on the invitation of Sir E. Sharpey Schafer, to hold the next meeting in Edinburgh in 1923.

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